SEWAGE AND INDUSTRIAL WASTES

(Formerly Sewage Works Journal)

JOURNAL of the FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS

Special Features

Sewage Treatment in Low-Temperature Areas—Thomas

Hydraulics of Storm-Water Inlets—Li, Geyer and Benton

Polarographic Metals Determination—Butts and Mellon

Water Pollution Abatement—Hollis

JANUARY, 1951—VOL. 23, No. 1

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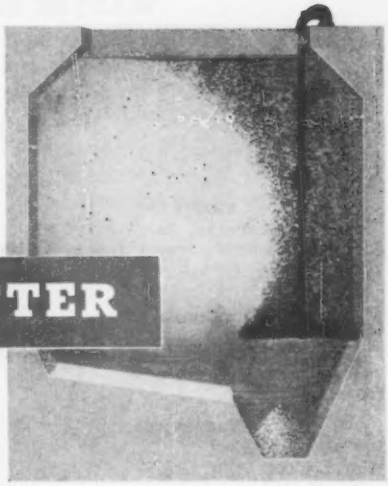

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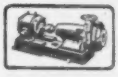

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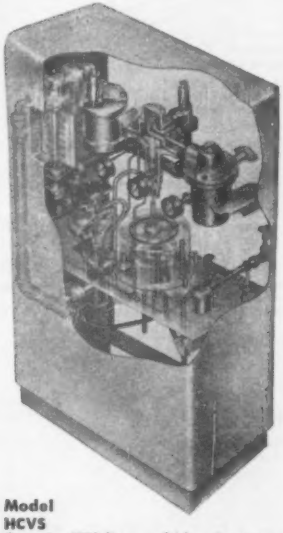

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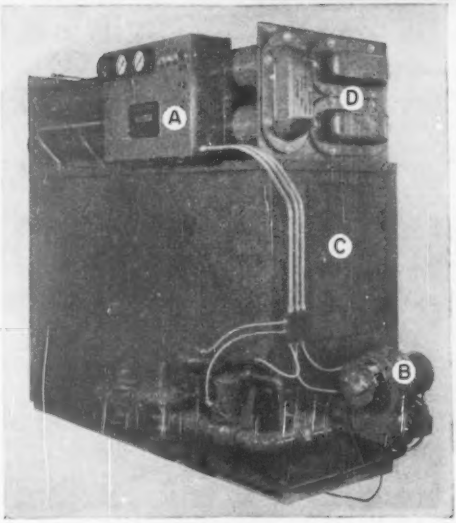

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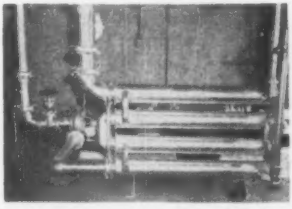

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Association	*Place*	*Time*
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Texas Water and Sewage Works Association	Texas A. & M., College Station, Tex.	Mar. 11–15, 1951
New Jersey Sewage and Industrial Wastes Association	Haddon Hall, Atlantic City, N. J.	Mar. 14–16, 1951
Arizona Sewage and Water Works Association	El Tovar Hotel, Grand Canyon, Ariz.	Mar. 28–30, 1951
Louisiana Conference on Water Supply and Sewerage	Louisiana State University, Baton Rouge, La.	Mar. 28–30, 1951
Virginia Industrial Wastes and Sewage Works Association	Hotel Chamberlin, Old Point Comfort, Va.	Apr. 5–6, 1951
Arkansas Water and Sewage Conference	Hot Springs, Ark.	Apr. 9–11, 1951
Kansas Sewage Works Association	Lamer Hotel, Hays, Kans.	Apr. 11–13, 1951
Montana Sewage Works Association	Hotel Placer, Helena, Mont.	Apr. 19, 1951
California Sewage Works Association	Hotel Californian, Fresno, Calif.	Apr. 25–28, 1951
Pacific Northwest Sewage Works Association	Hotel Vancouver, Vancouver, B. C.	May 15–16, 1951
Michigan Sewage and Industrial Wastes Association	Hotel Pantlind, Grand Rapids, Mich.	June 4–6, 1951
Ohio Sewage and Industrial Wastes Treatment Conference	Neil House, Columbus, Ohio	June 20–22, 1951
Kentucky-Tennessee Industrial Wastes and Sewage Works Association	Kentucky Hotel, Louisville, Ky.	Sept. 17–19, 1951
Missouri Water and Sewerage Conference	St. Joseph, Mo.	Sept. 30–Oct. 2, 1951

Federation of Sewage and Industrial Wastes Associations
Municipal Auditorium, St. Paul, Minn.
October 8–11, 1951

North Carolina Sewage and Industrial Wastes Association	Robert E. Lee Hotel, Winston-Salem, N. C.	Nov. 12–14, 1951

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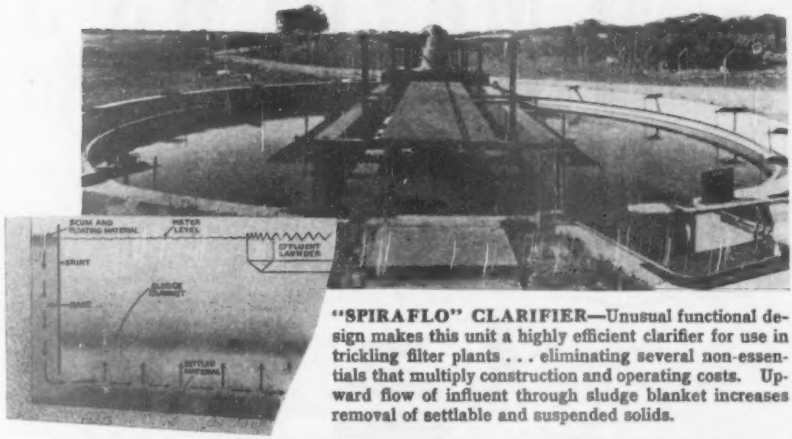

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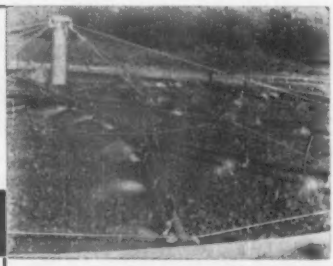

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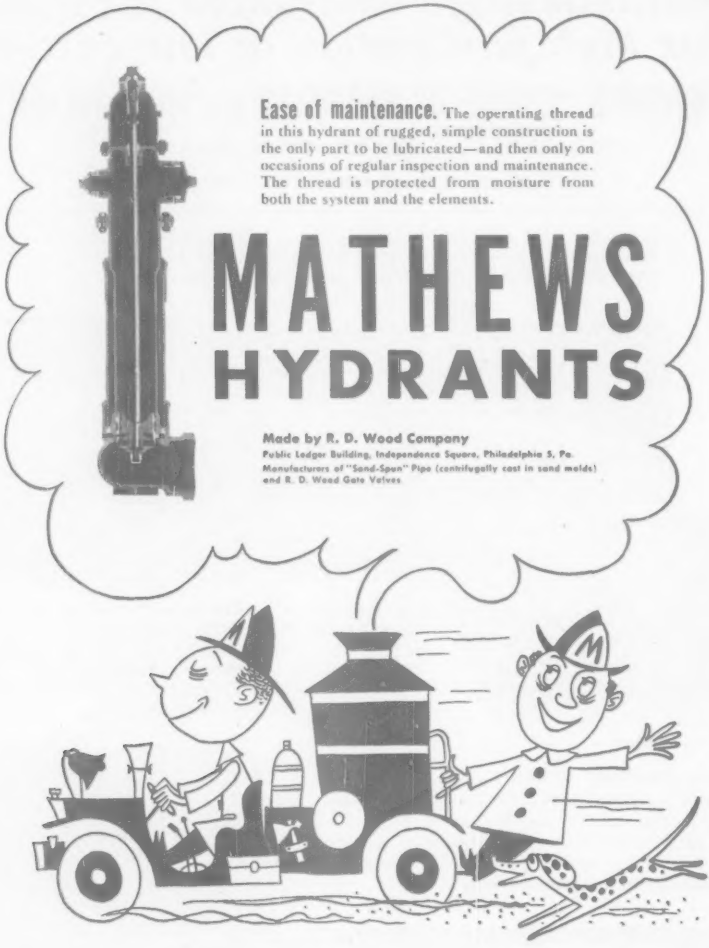
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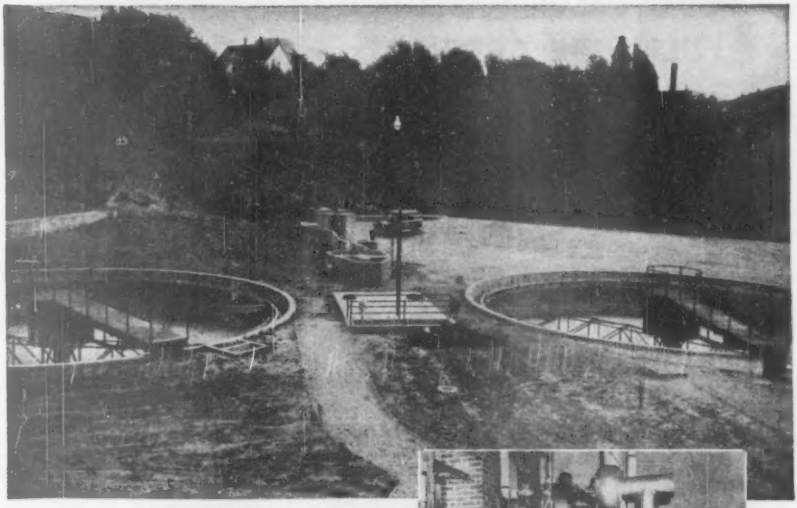

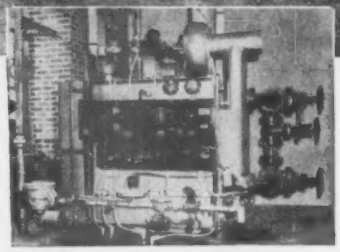

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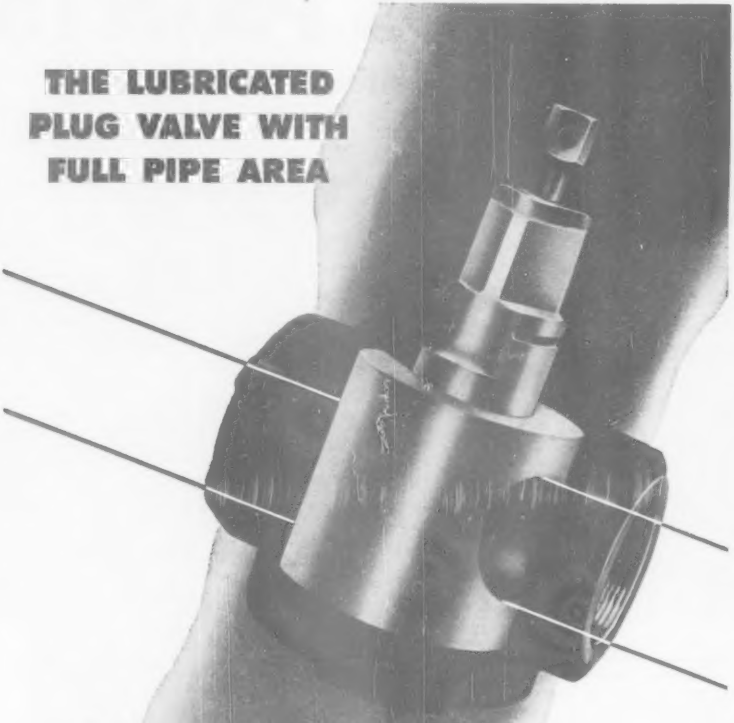

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makes it possible. Straight-through openings result in smooth, non-turbulent flow, lowest head loss, reduced valve abrasion. Yet compact valve construction is retained in both rectangular and round-port types. Reason enough for a.c.f. Lubricated Plug Valve preference.

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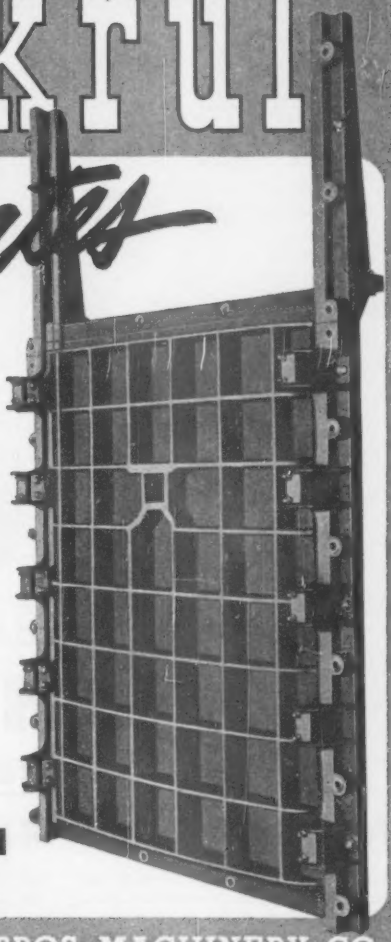

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Every installation of the Process Oxidator proves this revolutionary new sewage treatment process *gives the results of intermediate treatment at practically the cost of primary treatment.*

*Patented and Patents Pending.

For complete information regarding this one tank combination aeration, coagulation and sedimentation process send for Bulletin 106. Or if you have a particular problem, write to either address below and one of our specialized Engineers will be glad to assist you.

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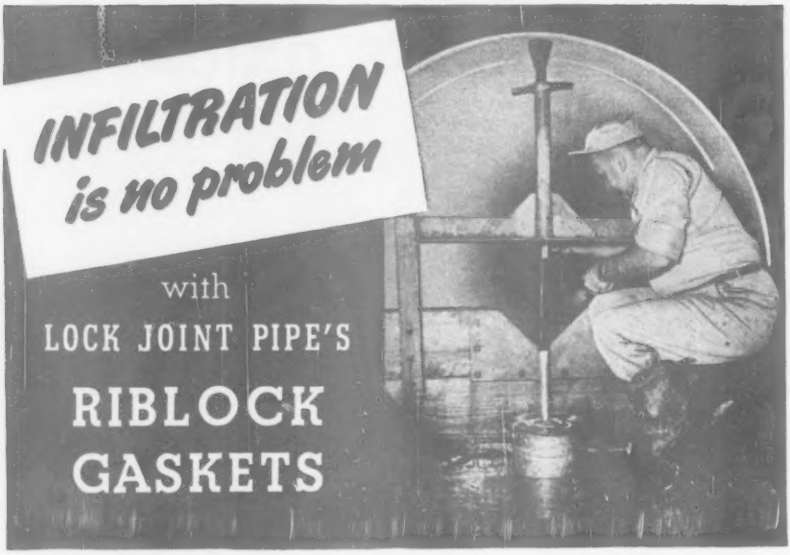

Actual field tests made on pipe laid under severe ground water conditions prove that the problem of infiltration can be overcome by using Lock Joint Reinforced Concrete Sewer Pipe equipped with Riblock Gaskets.

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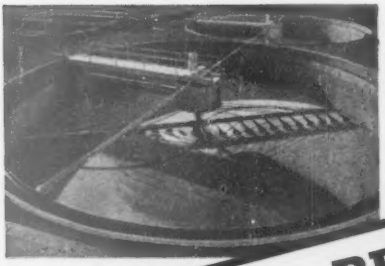
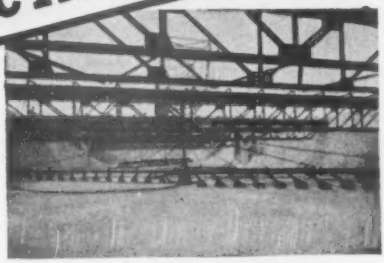


ROUND or RECTANGULAR



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****Prevents Septicity*** since sludge is in the settling tanks a shorter time.

****Greater Operating Flexibility*** since sludge may be drawn off at a faster rate . . . even a light blanket . . . without dilution.

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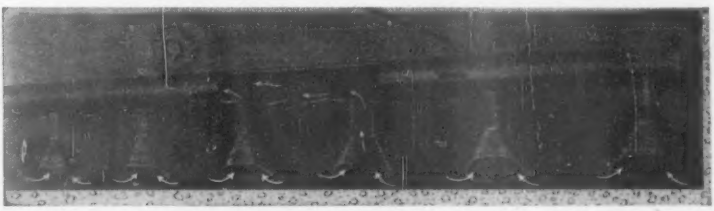
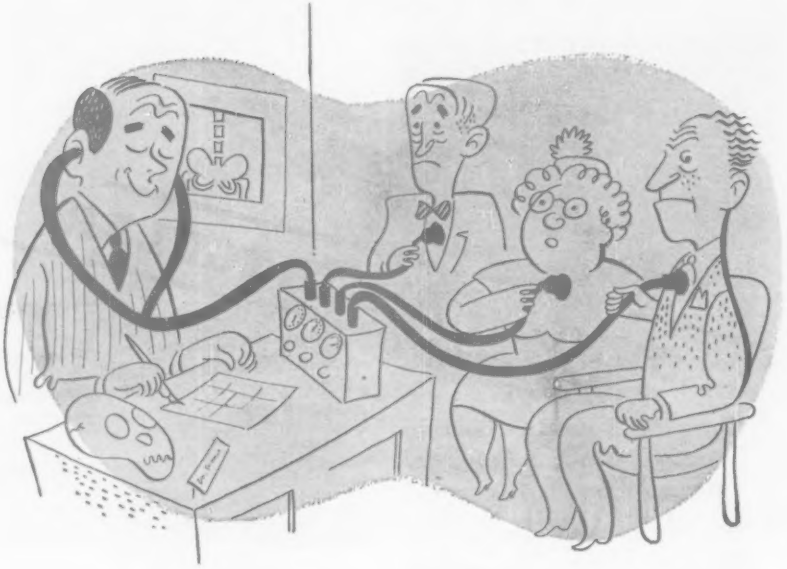


Arrows indicate direction of sludge removal from tank bottom with Rex Tow-Bro.

CHAIN BELT COMPANY REX SANITATION EQUIPMENT



Reduced Treatment Costs

LESS LOAD at the disposal plant—and, therefore, a reduction in sewage treatment costs—is one of the practical advantages that often result from the use of Transite* Sewer Pipe.

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(1) Transite's special sleeve-type joints that cut sewer line infiltration to a minimum.

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Besides the immediate saving in treatment costs, this reduction in load also enables plant capacity to be conserved for future needs. And, where new treatment facilities are planned, it permits consideration of a smaller plant . . . with possible important economies in disposal equipment.

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Transite Sewer Pipe is made of asbestos, cement and silica by a special method of manufacture which develops high, uniform strength and resistance to corrosion. It is available in four strength classes in sizes to 36". This permits selection of the pipe best suited to trench conditions, frequently eliminates the need for concrete cradles.

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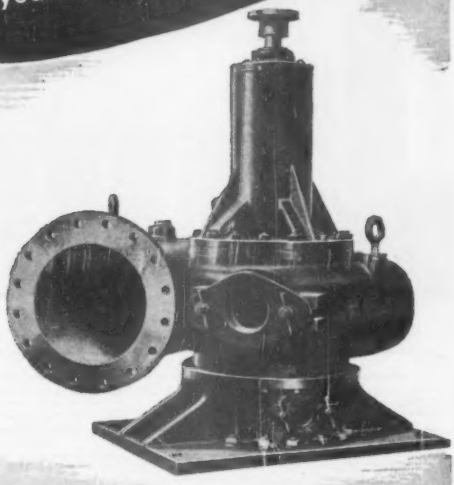

The Mixed Flow Volute Pump illustrated is just one of the many types in the extensive line manufactured by Economy Pumps, Inc. Available in capacities to 80,000 G.P.M., it is designed for service where large volumes of liquids without heavy solids are to be handled at high speeds.

Maintenance expense is held to a minimum. Case records show Economy Pumps operating for fifteen to twenty years without replacement of major parts. However, should repairs be necessary, all parts subject to wear are renewable.

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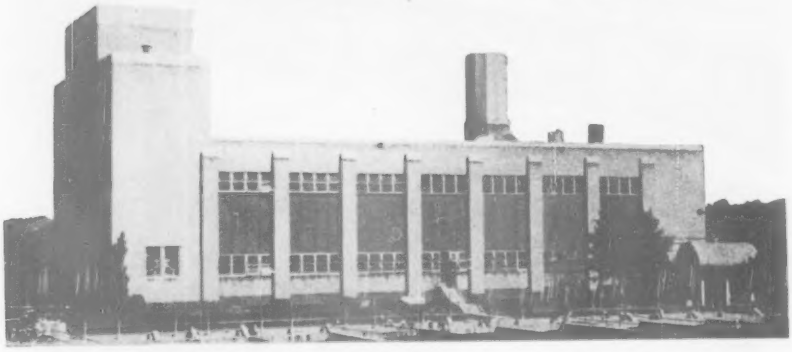
Centrifugal, Axial and Mixed Flow Pumps for all applications

Economy Pumps Inc.

DIVISION OF HAMILTON-THOMAS CORP., HAMILTON, OHIO

Low Cost Sludge Incineration

Low cost operation of Nichols Multiple Hearth Incineration at Minneapolis-St. Paul Sanitary District proved over a ten-year period.



Year	Tons Incinerated		Total Cost Operation & Maintenance	
	Dry Solids	Wet Cake	Per Ton Dry Solids	Per Ton Wet Cake†
1940	37,091	116,000	$1.36	$.436
1941	35,993	112,000	1.23	.394
1942	33,838	106,000	1.17	.375
1943	32,955	103,000	1.39	.445
1944	33,758	105,500	1.27	.407
1945	32,428	101,000	1.38	.442
1946	33,581	105,000	1.54	.493
1947	36,633	114,000	1.42	.455
1948	34,549	108,000	1.79	.573
1949	34,787	108,500	1.73	.554
Average	34,56.13	107,900	$1.43	$.457

†Based on average of 68% moisture in filter cake

When increasing population requirements necessitated additional incinerator capacity, the Nichols Multiple Hearth Furnace was again selected. This fourth unit will be in operation shortly.

The operation costs shown in the table* include all salaries, wages, materials, supplies, power, light, water and miscellaneous charges. Also accounted for are all labor costs and materials required for maintenance of the sludge incinerator equipment.

Despite steadily increasing hourly rates for labor and increasing prices of materials and supplies, the attention to operation and maintenance given by the staff has kept operating costs per ton at a low level.

*Figures taken from Annual Reports of Minneapolis-St. Paul Sanitary District 1940-1949.

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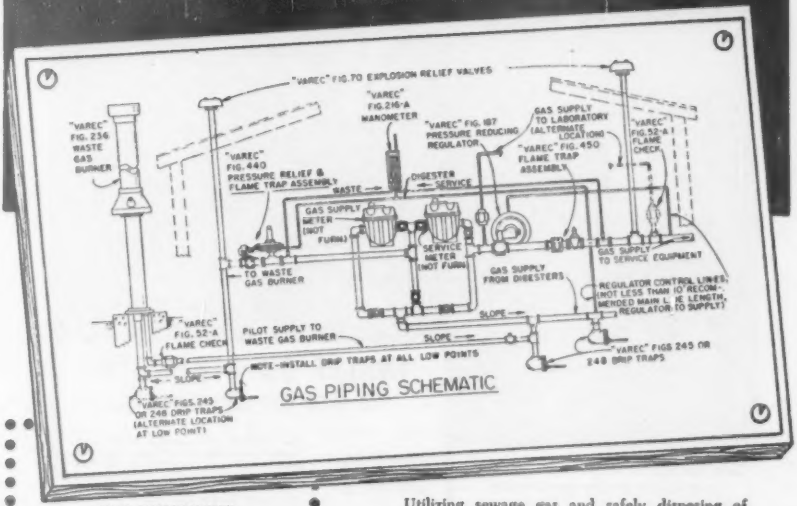
"VAREC" figures in *Your* SEWAGE TREATMENT PLANT DESIGN for SAFETY and GAS CONTROL


"VAREC" FIG. 70 EXPLOSION RELIEF VALVES
"VAREC" FIG. 236 WASTE GAS BURNER
"VAREC" FIG. 216-A MANOMETER
"VAREC" FIG. 187 PRESSURE REDUCING REGULATOR
GAS SUPPLY TO LABORATORY (ALTERNATE LOCATIONS)
"VAREC" FIG. 52-A FLAME CHECK
"VAREC" FIG. 450 FLAME TRAP ASSEMBLY
"VAREC" FIG. 440 PRESSURE RELIEF & FLAME TRAP ASSEMBLY
WASTE
DIGESTER SERVICE
GAS SUPPLY METER (NOT FURN.)
SERVICE METER (NOT FURN.)
GAS SUPPLY TO SERVICE EQUIPMENT
TO WASTE GAS BURNER
GAS SUPPLY FROM DIGESTERS
REGULATOR CONTROL LINES (NOT LESS THAN 10 RECOMMENDED MAIN L. IE LENGTH, REGULATOR TO SUPPLY)
"VAREC" FIG. 52-A FLAME CHECK
PILOT SUPPLY TO WASTE GAS BURNER
SLOPE
SLOPE
SLOPE
NOTE—INSTALL DRIP TRAPS AT ALL LOW POINTS
"VAREC" FIGS 245 OR 248 DRIP TRAPS
"VAREC" FIGS. 245 OR 248 DRIP TRAPS (ALTERNATE LOCATION AT LOW POINT)
GAS PIPING SCHEMATIC

GAS EQUIPMENT SPECIFICATIONS

a. **PRESSURE RELIEF AND FLAME TRAP ASSEMBLY**
"VAREC" Fig. No. 440

b. **FLAME TRAP ASSEMBLY**
"VAREC" Fig. No. 450

c. **FLAME CHECK**
"VAREC" Fig. No. 52A

d. **EXPLOSION RELIEF VALVES**
"VAREC" Fig. No. 70-1

e. **WASTE GAS BURNER**
"VAREC" Fig. No. 236

f. **DRIP TRAPS**
"VAREC" Fig. No. 245 (automatic)
"VAREC" Fig. No. 248 (hand operated)

g. **MANOMETERS**
"VAREC" Fig. No. 216A

"Varec" PROVED and APPROVED

Utilizing sewage gas and safely disposing of excess gas is an automatic operation with "VAREC" Equipment incorporated into your sewage plant design. With this equipment, accurate gas pressures are maintained in all service lines. As soon as the digesters make more gas than required for service, the pressure relief valve to the waste gas burner opens to permit safe burning of the excess.

Flame flashback to valuable equipment is prevented with "VAREC" Flame Traps and Flame Checks. The flame arresting element of the Flame Trap is designed to eliminate flame propagation of even more inflammable gases than encountered in sewage service. This element is the same as that used in "VAREC" Flame Arresters listed by the UNDERWRITERS' LABORATORIES for petroleum product storage.

Emergency explosion relief is accomplished with "VAREC" Explosion Relief Valves. These valves should be installed outside of any buildings.

An enlarged engineering drawing of the above gas piping detail will be sent upon request. If you design sewage treatment plants, write today.

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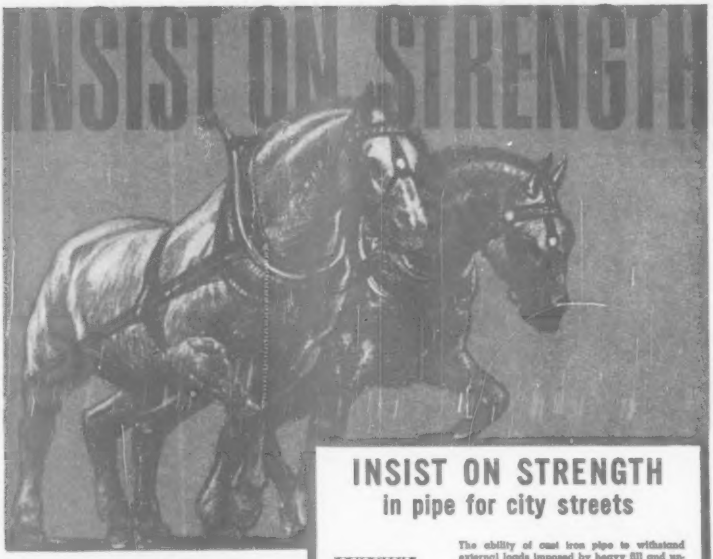

Long life and low maintenance cost of mains laid under city streets depend not only on effective resistance to corrosion but on definite strength factors. The four strength factors that pipe must have to withstand beam stress, external loads, traffic shocks and severe working pressures, are listed in the box opposite. No pipe that is deficient in any of these strength factors should ever be laid in paved streets of cities, towns or villages. Cast iron water and gas mains, laid over a century ago, are serving in the streets of more than 90 cities in the United States and Canada. Such service records prove that cast iron pipe not only resists corrosion but combines all the strength factors of long life with ample margins of safety.

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in pipe for city streets

CRUSHING STRENGTH — The ability of cast iron pipe to withstand external loads imposed by heavy fill and unusual traffic loads is proved by the Ring Compression Test. Standard 6-inch cast iron pipe withstands a crushing weight of more than 14,000 lbs. per foot.

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SEWAGE AND INDUSTRIAL WASTES

Journal of the Federation of Sewage and Industrial Wastes Associations

Volume 23 JANUARY, 1951 Number 1

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to preaerate sewage and industrial wastes . . .

the low cost **DORRCO AERATOR-CLARIFIER**

The new Dorrco Aerator-Clarifier is a compact, low-cost unit combining the functions of *preaeration*, *flocculation* and *sedimentation* in a single tank. It is applicable wherever it is advantageous to increase suspended solids and B.O.D. removals—where odor control or elimination is necessary—or where flocculation with or without chemicals, is beneficial. It fits equally well into primary or secondary treatment flowsheets . . . with notable advantages in both.

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2. **No solids interference in aeration chamber** . . . grit and heavier solids settle quickly, avoiding interference with flocculant material.
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4. **Minimum of short circuiting** . . . spiral-flow aeration effect in Aerator minimizes short circuiting.
5. **Simple maintenance** . . . aeration tubes are removable for cleaning or replacement without interfering with operation of the unit.
6. **Low cost** . . . single tank and simple design cut installed cost.

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RESEARCH ENGINEERING EQUIPMENT

Sewage Works

SEWAGE TREATMENT IN LOW-TEMPERATURE AREAS

By Harold Allen Thomas, Jr.

An Investigation for the
SUBCOMMITTEE ON WASTE DISPOSAL
of the
COMMITTEE ON SANITARY ENGINEERING AND ENVIRONMENT
NATIONAL RESEARCH COUNCIL
DIVISION OF MEDICAL SCIENCES
WASHINGTON, D. C.

Sewage treatment installations considered in this report are those designed for permanent or semi-permanent communities of large size in the low-temperature areas of Alaska and Canada. Devices, such as septic tanks, suitable for small or temporary posts are not considered.* Particular interest is centered on design and operational problems of sewage plants for military posts.

While it may be anticipated that most of the various reasons for sewage treatment in temperate climates will apply in differing degrees in the North, it is probable that the principal purpose will be the prevention of pollution of surface waters needed for water supply. A high incidence of enteric infections in many Alaskan communities, stemming largely from lack of adequate methods of excreta disposal, has been cited as a reason for adoption of sewage treatment (1a). Williams (1b) states that "reports of gastro-enteric diseases associated with high fever, marked diarrhea, and dysentery have been received by the Alaska Department of Health from time to time during the past 15 years. These reports have originated in all parts of the Territory of Alaska." Several cases of typhoid fever have been recorded by the U. S. Commissioner at Barrow, Alaska. Sanitary conditions have been such that the Alaska legislature in 1949 enacted a water pollution control act (Chap. 117, S. B. 61).

It may be expected that sewage treatment requirements at different sites will vary considerably; fixed installations near deep water or in remote areas may not require sewage treatment.

Existing Sewage Treatment and Disposal Facilities in the North

The Alaska Department of Health, in a bulletin entitled, "The Community Facilities in Alaska" (1949), states that none of the 58 communities with a population greater than 200 has a completely satisfactory sewage disposal system. A total of 45 of these utilize only privies, cesspools, and private sewers; the other 13 discharge

* A recent investigation pertaining to these is summarized in a publication of the U. S. Public Health Service, "Survey of Information on the Freezing Aspects of Household Sewage Disposal Systems."

raw sewage into rivers or tidal estuaries. Two systems are provided with primary treatment facilities (settling tanks), but because of high operating costs these are not being used.

In smaller and more remote communities in the permafrost region, elementary systems of sewage disposal are the rule. At Barrow, chemical toilets are used and the contents are placed in empty oil drums, which in summer are hauled to a nearby ravine and dumped; in winter the drums are placed on sea ice. Septic tanks are operated successfully in a permafrost at a number of small communities—Bethel and Tanana, for example.

South of the permafrost zone, sewage treatment practice accords more closely with that of the northern United States. Berry (2a) reported that there are 126 municipal plants in Canada (1946), of which 69 provide complete treatment. Activated sludge plants outnumber other complete treatment plants two to one. Sludge digestion facilities are common, some plants having glass-covered sludge beds.

Of particular interest in the matter of treating sewage under extreme climatic conditions are the sewage works at Flin Flon (4) and Sherridon (5) in Manitoba. Experiences at other sewage plants in the provinces of Manitoba and Saskatchewan are described by Taylor (6). An informative review of the development of sewage treatment in North Dakota, a state having long cold winters, has been presented by Lauster (7).

Climatological Factors Affecting Sewage Treatment

Foremost among the factors affecting sewage plant design and operation in the North is the cold, which exceeds that of the continental United States

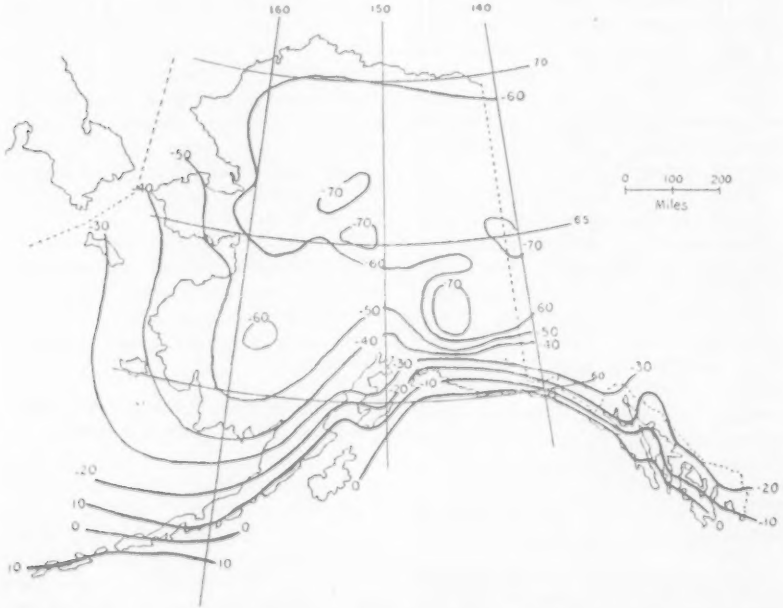


FIGURE 1.—Approximate minimum recorded Fahrenheit temperatures in Alaska (based on U. S. Weather Bureau data).

in both degree and duration. In some areas, critical ranges for design lie between −50° and −70° F. Temperature variation may be rapid; changes of more than 20° F. per hour are frequently experienced at the fringes of the polar air mass. Pertinent temperature data for Alaska compiled by the U. S. Weather Bureau are shown in Figures 1, 2, and 3.

An indication of the duration of periods of low temperature may be had from the following compilation based on U. S. Weather Bureau data. An outline map of Alaska (Figure 4) shows the location of the communities listed.

Community	No. Days Max. Temp. 32° F. or Less	Community	No. Days Max. Temp. 32° F. or Less
Adak	30	Kotzebue	205
Anchorage	125	McGrath	165
Barrow	280	Nome	185
Bethel	140	Northway	165
Cordova	60	Petersburg	30
Fairbanks	160	Seward	70
Galena	180	Sitka	20
Gambell	205	Skagway	50
Homer	90	Umiat	240
Juneau	55	Valdez	95
Kenai	120	Wasilla	110
Ketchikan	30	Wrangell	25
Kodiak	30		

Wind velocities are high relative to those farther south. A velocity of 125 m.p.h. has been used as a basis of design for a number of utility structures.

Another factor affecting construction is the soil, which may be permanently frozen down to depths of several hundred feet. This poses an especially difficult problem in the design of sewage treatment devices that inherently must have warm, or even hot, interiors. Differential settling and frost heaving may be expected to interfere seriously with the performance of tanks and filters, the proper functioning of which is contingent up-

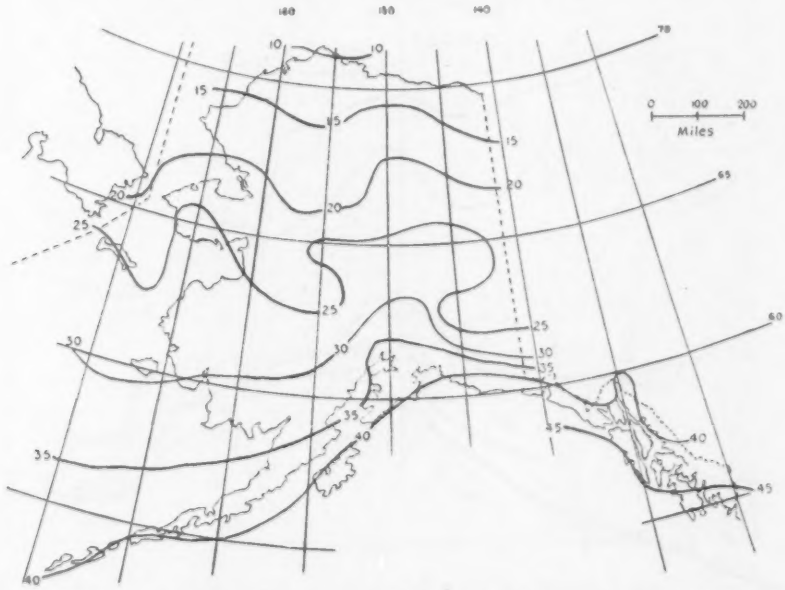


FIGURE 2.—Approximate mean annual Fahrenheit air temperatures in Alaska (based on U. S. Weather Bureau data).

on precise alignment along a hydraulic grade line.*

Still another factor stems from the necessity of maintaining heat in sewer lines. Raw sewage arriving at a plant after passage through steam-heated sewers or utilidors and pumped at stations designed to eliminate or minimize free air surfaces (for example, steam ejectors) may be expected to be staler than would be the case were it possible to use conventionally ventilated sewers. Problems of corrosion, odor, and reduced treatability may be incurred.

One circumstance pertaining to sewage treatment in the Arctic is that water supplies have average temperatures several degrees colder than those common in the continental United States. Moreover, present surveys indicate that most Arctic supplies are somewhat more highly mineralized than supplies in the States. In particular, a relatively high concentration of sulfate has been noted in many surface waters.

A final factor deriving from the cold is that less reliance may be placed on natural self-purification of effluents in receiving waters. Biochemical reactions are slowed to a marked extent in waters just above the freezing point; bacterial die-away rates are greatly reduced. The implication is that higher degrees of treatment may be necessary in Northern sewage plants than in a warmer climate in order to achieve a requisite degree of pollution abatement in a receiving stream used for water supply.

* A comprehensive discussion of construction problems in permafrost areas is presented in "Permafrost or Permanently Frozen Ground and Related Engineering Problems" compiled by S. W. Muller and published by J. W. Edwards, Inc., Ann Arbor, Mich. (1947).

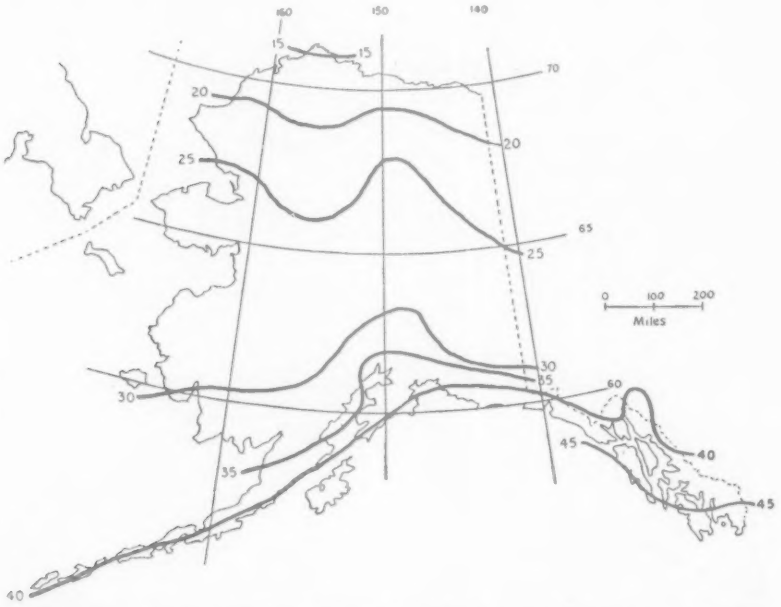


FIGURE 3.—Approximate mean annual Fahrenheit ground temperatures in Alaska at 8-ft. depth (based on U. S. Weather Bureau data).

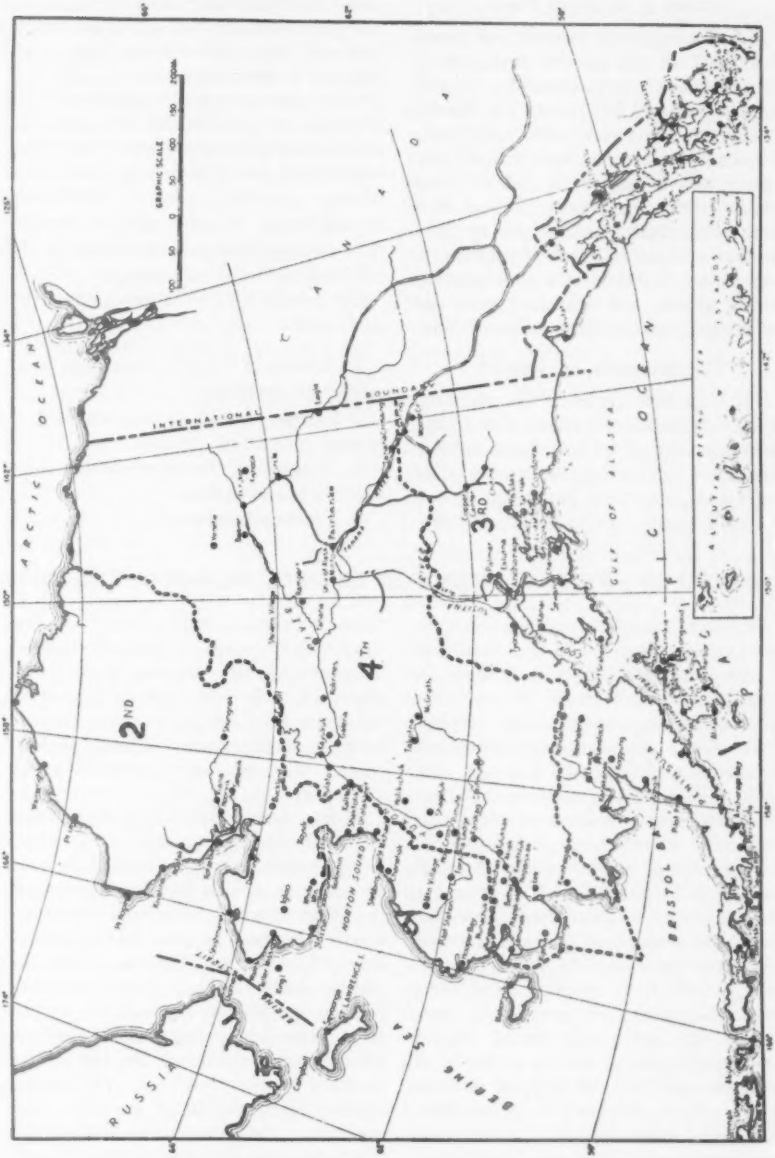


FIGURE 4.—Map of Territory of Alaska.

Factors Pertaining to Sewage Treatment at Military Posts

It is reasonable to assume that many, if not all, of the special problems of sewage treatment imposed by a military regime will be operative at Northern posts. Environmental conditions at military establishments lead to production of sewage that differs from municipal sewage chiefly in that it is more concentrated, has a greater proportion of volatile matter relative to total solids, contains a higher proportion of grease, and exhibits larger and more rapid variations in diurnal flow.

Organization of Report

The objective herein is the examination of factors that affect the design and operation of sewage plants at military posts in Northern latitudes. The method of approach has been to collect and analyze information pertaining to existing plants, both military and municipal, that have operated under conditions of extreme cold. It is believed that two factors above all others are important in the kind of sewage plants being considered—the duration of periods of extreme cold to be encountered are longer than have been experienced elsewhere, and populations in military posts in the North, as elsewhere, will be subject to sudden drastic changes, particularly in times of national emergency.

The study is divided into four parts, as follows:

1. Effects of frigid climate on sewage plant operation.
2. Effects of cold on performance of sewage treatment process.
3. Methods of weatherproofing sewage treatment plants.
4. Recommendations.

EFFECTS OF FRIGID CLIMATE ON SEWAGE PLANT OPERATION

From a historical viewpoint, the problems arising from the necessity of operating sewage plants during periods of cold and storm have always been of first importance in the development of the art of sewage treatment in Europe and in North America. Indeed, differences in modern practice in various countries have to a large extent come about from differences in the severity of winters. Moreover, it may fairly be noted that in no country has the art of weatherproofing sewage plants progressed to a point beyond that just necessary to meet the exigencies of local winter conditions. Treatment works are commonly situated in the open and spread over a considerable area; during periods of unusual cold or prolonged winter storms they are often vulnerable. Difficulties may be merely operational inconveniences or they may be so overwhelming as to cause complete plant breakdown. Recently, in England, where sewage treatment has been practiced for over a half century, a succession of three severe winters resulted in a number of complete plant stoppages (8). It is not an exaggeration to state that in all regions severe weather often occasions operating difficulties that in some instances recur annually.

Winter-borne difficulties in a plant are likely to be cumulative. A defect at one point in a plant caused by cold or storm is apt to have consequences, the effect of which will spread progressively to interfere with the performance of other plant units. For example, sludge drying beds that have become overloaded during the winter as a result of inadequate capacity or insufficient attention on the part of the operator may result in overloaded sludge digesters; these in turn may result in a deterioration in the quality of supernatant returned to the primary settling tanks; these units are apt thereby to perform with impaired efficiency, with the result that secondary

units become overloaded. Solids in the primary effluent, coupled with freezing, may put the filter distribution system partly out of service. With poor distribution and heavy loading, the effluent will deteriorate and the entire plant may go out of kilter.

Winter difficulties may be attributed to sources that fall into two categories, as follows:

1. Minor deficiencies of design or operation, such as control valves sited in positions exposed to cold winds, lack of screens to protect filter nozzles, lack of provision for draining tanks, and lack of suitable lighting for nocturnal inspections.

2. Major defects in design, such as inadequate capacity of or means for maintaining heat in important plant units. This report is concerned primarily with the second category, but it is not out of place to stress the importance of the first.

Hurley (8) has presented a thoughtful discussion of minor aspects of design and operation pertaining to cold-weather operation. Berry (2b) also has made a perceptive study of cold-weather difficulties of sewage plants. Especially important among the points of design that fall in the first category are those that pertain to the safety and comfort of operating personnel. To provide men with facilities for walking in safety, working without unreasonable exposure, and seeing with ease is to make a real contribution toward elimination of cold-weather trouble. It is certain that with forethought on the part of the designer and ingenuity and resourcefulness on the part of the operator, many of the problems that beset sewage plants during cold periods may be countered successfully.

The following sections are devoted to a discussion of major cold-weather difficulties in the operation of the various types of plant units that have resulted primarily from lack of weatherproofing and heating.

Pretreatment Units

Universal experience in sewage plants in the northern U. S. and Canada with screens, bar racks, shredders, comminutors, detritus tanks, and grit chambers has been that these units, which must be frequently inspected and cleaned, may be subjected to icing to such an extent as to render maintenance difficult or impossible unless covering or housing is provided. It would appear that in plants designed for operation in the far North, housing is a necessity for pretreatment units, together with pumps and flow-measuring equipment.

Settling Tanks

Of all sewage treatment devices in common use, settling tanks appear to be least vulnerable to cold. Taylor (6), in commenting on operational results in five small sewage plants in Manitoba and Saskatchewan during the winter of 1944–45, when temperatures seldom were greater than 0° F. and sometimes reached − 35° F., concluded that small clarigesters could successfully withstand the rigors of the climate. Kleven (9), at Grand Forks, N. Dak., reported that no difficulties were encountered in the operation of an open primary clarifier (35 ft. diameter by 8 ft. deep) with a rotary sludge scraper mechanism during eight years of all kinds of weather, including that with temperatures of −35° to − 40° F. He found that no advantages accrued to a covered clarifier of the same size and loading operated in parallel with the open one described. Arnold (11) measured the temperature of the flow through an open clarifier (35 ft. diameter by 8 ft. deep) handling sewage from Grafton, N. Dak. (population 5,160) after an extended period of cold weather during which temperatures fell to − 25° F. He found the following average temperatures during a 24-hr. period, February 9, 1947; air, 0.4° F.; raw sewage, 49.8° F.; clarifier

effluent, 48.2° F. During this period no operational difficulty was experienced.

Secondary settling tanks, on the other hand, have not infrequently been subjected to icing difficulties. Cleland (10) observed the formation of sheet ice up to a thickness of 2 in. on humus tanks following trickling filters. The ice has to be broken up during periods of sludge removal in order not to foul the pumps. Similar conditions have been noted by Hardenbergh at Liberty, N. Y.

The chief difficulties experienced in the operation of settling tanks during intervals of low temperature have resulted from the interference of ice with sludge and scum removal mechanisms. These devices now seem for the most part to have been successfully adapted to function properly despite the rigor of the climate in the northern U. S. and Canada.

Two factors, however, militate against the use of open settling tanks in the extreme cold of the far North; namely, the loss of heat needed for the proper action in secondary oxidizing units and in outfall lines, and the formation of sheet ice of sufficient thickness to endanger tanks structurally. Although the thin ice sheets that have been described may have no particular deleterious effect on operation, sheets of several inches in thickness that theoretically could form under Aretic conditions (12) (13) could easily muster sufficient compressive strength to break tanks if the operating staff did not persist in breaking up the formation. These factors are especially significant in sewage plants at military posts, where periods of inactivity may result in low flows and long detention periods.

Trickling Filters

Despite their merits in other respects, trickling filters have always been found to be one of the sewage treatment devices most vulnerable to cold weather. In many parts of the Midwest it has become almost standard practice to provide cover for filter units. This has increased the cost of construction, but the justification has been in the fact that little operational trouble has been experienced, even in severe climates, with housed filters. There can be little doubt that housing is indicated for trickling filters in the far North, except perhaps under unusual mitigating circumstances (for example, seasonal operation).

The chief problem is how much, if any, heat should be provided in housed filters to augment that present in the sewage. In this connection it is worthwhile to note that recent advances in the technology of filter distribution mechanisms have considerably enhanced the ability of filters to withstand adverse weather. No insuperable difficulty was reported in the operation of open filters at more than 300 military posts in the continental U. S. during World War II (14). An assessment of the capacity of modern open filters to endure low temperatures is necessary in an evaluation of the heating requirement of closed filters subjected to the extreme climatic conditions of the Aretic.

A detailed description of the action of an open filter during an extended cold spell terminating in a severe blizzard has been recorded by Arnold (11). Ice accumulation was marked during the storm, and large amounts of snow were trapped by the spray during the dosing cycle. It was estimated that 95 per cent of the filter was covered with ice, openings being confined to the immediate vicinity of nozzles. The accumulations were on the surface of the filter; large blocks were pried from the bed with a pinchbar, with some of the top stone embedded in the ice. During this period the filter removed 53 per cent of the applied B.O.D. load; a closed filter in parallel and loaded equally removed 61 per cent of the applied B.O.D.

Despite this remarkable performance, observers were of the opinion that the open unit was subjected to about its ultimate capacity to withstand the weather—with continued cold and snow it would probably have been necessary to remove the unit from service.

Taylor (6) concluded from a comparison of operational experiences with open and closed filters in Manitoba that the former were not satisfactory for the climate.

Madison (15) found that wind, rather than cold, determined the rate and amount of ice formation on two standard open filters with rotary distributors at Winner, S. Dak. Temperatures as low as −24° F. failed to cause icing if wind velocities were less than 5 m.p.h. However, high winds of 25 to 35 m.p.h. caused freezing with air temperatures as high as 20° F. Ice formation varied from 0.5 in. in thickness on the upwind side to 8 in. on the downward side. Ice-balls were observed to form first, then interstices filled, until finally only a few holes remained to admit sewage. At this stage, with continued wind the ice accumulation built up rapidly; pickaxes were used in breaking the formation to keep the units in operation. When the wind ceased, ice layers as thick as 6 in. were melted in 4 hr. although the temperature was −1° F. No particular improvement in regard to icing resulted when one filter was taken out of service, recirculation shut off, and the entire flow routed through the remaining filter. The operator planned to install a canvas windbreaker 5 ft. in height to lessen the icing caused by the high wind.

Hurley (8) lists cold-weather difficulties. Another adverse effect of wind may be the slowing of the rotating distributor, especially during periods of low flow experienced in trickling filter plants in England. These include:

1. Blocking of orifices, causing uneven distribution.
2. Stalling of distributors, owing to trouble with traction drives or haulage ropes.
3. Distributors with small orifices, especially those types prone to stand still and dribble.
4. Non-uniform tension in distributor guy ropes.
5. Freezing of liquid distributor seals (antifreeze liquid being diluted by snow and ice).

Keefer (16) emphasizes the importance of providing bleeder valves in filter distribution systems to prevent pipes and nozzles from freezing. He describes conditions during the severe winter of 1933–34, when it became necessary to remove all nozzles at Worcester, Mass., to prevent freezing. He also points out, as have others, that it is often desirable to alter the shape of the outside spray pattern to prevent icing of filter walls.

Cleland (10) states that trickling filters at State College, Pa., caused much trouble during cold weather. Difficulties were considerably magnified by nozzle clogging from solids passing through improperly functioning Imhoff tanks. Clogged nozzles caused freezing in laterals. This was relieved only by the expedient of building fires on the filter bed. Skinner (17) described special flat-spray nozzles designed to lessen ice formation on filters at Rochester, N. Y. The original nozzles (which continued in use during warm weather) had high trajectories and caused ice formations 4 ft. deep to build up. Ice-free area was limited to a 3-ft. radius around the nozzles.

A discussion of the weatherproofing requirement of trickling filters in the far North is presented in a subsequent section.

Activated Sludge Aeration Basins

Cold-weather difficulties with activated sludge units have generally been

less serious than with open trickling filters. Troubles due to freezing and snowing up have rarely been reported. The process inherently entails less exposure of sewage to cold dry winds; moreover, units are relatively compact and more easily protected by covers and windbreakers. Such troubles as have been reported are usually caused by improper functioning of other plant units (for example, overloading by bad primary tank effluents). Some difficulties have been described in mechanical aeration plants (8) due to icing of emerging paddles; such devices, however, are not common in North American practice.

The extensive use of the activated sludge process in Canada (2)(3) is indicative of its ability to function during periods of low temperature. In so far as military plants are concerned, however, this advantage is offset to a certain extent by the somewhat disappointing experience with the process during World War II (14). The high volatile and grease content of military sewage, the rapid variations in diurnal flow, and the frequent changes in loading due to shifts in contributory populations were, no doubt, important factors in the failure of the process to produce the degree of treatment commonly attained in municipal activated sludge plants.

Sludge Digestion and Disposal

The chief problem with heated sludge digesters engendered by cold weather is the added heat requirements to maintain adiabatic digestion. This subject is considered quantitatively in a subsequent section. Other difficulties that have been reported include the freezing of liquid seals on gas domes (22), maintenance of waste gas burners, and icing and uneven weighting by snow on floating covers. Most winter complaints, however, stem from inadequate sludge storage capacity rather than from difficulties with cold.

Reports of unsatisfactory Imhoff tank performance during cold weather have not been uncommon (10)(18). The causes have usually been overloading, lack of attention (cleaning, skimming, etc.), and insufficient heat in the sludge storage compartment.

Difficulties with sludge disposal during intervals of low temperature have been almost universal. The problems have been manifest in particular at small plants, where mechanical methods (conditioning, dewatering, incineration, etc.) are not practicable. The complaints have usually related to inability to remove sludge during inclement weather. The literature on the pros and cons of open *versus* glass-covered sludge drying beds is extensive and indicates that the question is one of economics, at least in so far as treatment in temperate zones is concerned. In practically all cases, cold-weather difficulties derive from beds that are inadequate as to size or as to drainage characteristics. Nearly every experienced operator knows that there is no easy solution to the problem of overloaded sludge beds. If repeated applications of sludge are made on top of semi-dry sludge, trouble is piled up for the future. Sludge is thereby deprived of effective drainage at the bottom and evaporation is limited because of excessive depth. The accumulated sludge may require such a long time to attain a spadable condition that it may happen that the next cold period must be met with an even more unfavorable situation as to sludge bed capacity.

All such difficulties, it may be expected, will be markedly increased in the Arctic. On the basis of the relative duration of periods of warm weather, it may be estimated that sludge beds in the North should have capacities from three to six times larger than those common in conservative practice in the States.

Sludge lagoons have provided temporary relief in many plants. However, a recent survey (19) has pointed

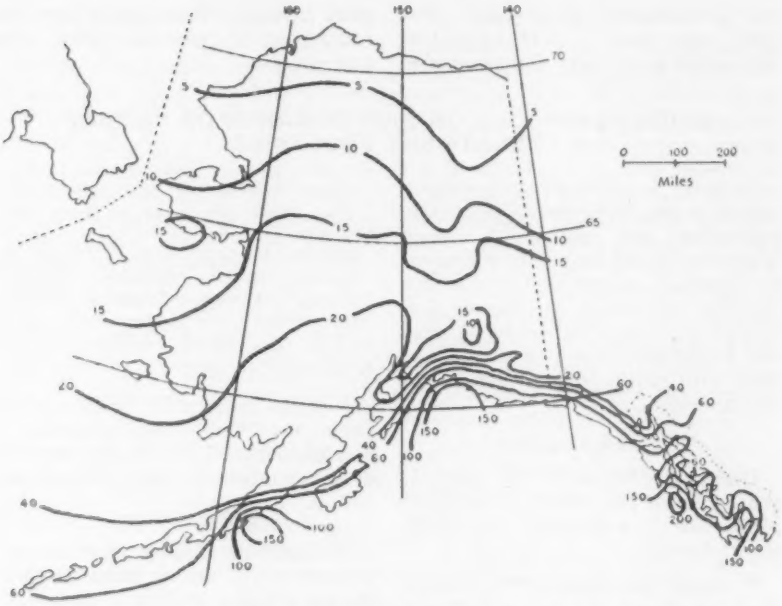


FIGURE 5.—Approximate mean annual inches of precipitation in Alaska (based on U. S. Weather Bureau data).

up the fact that these frequently are unsatisfactory in climates in which average monthly temperatures never exceed 60° F. In colder weather, digestion and consolidation proceed at a very slow rate, if at all. The chief objections to lagoons have been the space requirements (as high as 60 cu. ft. per capita) and odors occurring after the cold period when the sludge first warms up to temperatures greater than 60° F.

It should be noted, nevertheless, that in the far North some factors favor the use of lagoons. In the first place, land is not apt to be at a premium around Arctic sewage plants; also, despite the cold, drying rates may be substantial as a consequence of the high-velocity, dry winds that are prevalent. Moreover, large areas exist where the annual precipitation is less than 80 in. (Figure 5). Finally, it may be expected that drainability of sludge will be increased by the thorough freezing and subsequent thawing in a region where shallow lakes freeze completely to the bottom. The possibility of using freeze-thaw cycles in accelerating the dewatering of sludge has been discussed by Downes (20) on the basis of experience at Dunellen, N. J. At the Dunellen plant, results indicated that freezing of sludge (by ammonia refrigeration) greatly reduced the water content and with thawing rendered the material readily combustible by incineration.

Outfall Lines

In so far as it has been possible to ascertain, little difficulty has been experienced in the United States with freezing in outfall sewers. Effluents having enough heat to pass through secondary treatment units generally acquire a sufficient amount of motion in outfall lines to preclude serious icing difficulties. The situation in the

far North, however, is different. Alter (21) states that "Careful control of the outfall is necessary to prevent complete freezing. Steam tracer lines are often used to keep the outfall open and operable."

EFFECTS OF COLD ON PERFORMANCE OF SEWAGE TREATMENT PROCESSES

In order to evaluate more comprehensively the requirements for weatherproofing and heating of sewage plants in the low-temperature areas of the North, it is pertinent to consider the effect of cold on the organic content of raw sewage and on the physical and biochemical processes of stabilization, both within plants and in receiving waters.

Organic Loading

Higher amounts of B.O.D. and suspended solids per capita in Northern plants may be anticipated as a result of two factors:

1. Lower temperatures of water (less treatment in sewers, if not heated).
2. Less bivouacking (non-contributory population), as field manuvers will be more restricted during colder portions of the year.

The first factor is a relatively minor one, and at most probably would cause an increase in organic loading of the order of 10 per cent above that usual in sewage plants at military posts in temperate climates. The second factor may exert a sizable effect. The proportion of contributory (sewered) population to nominal population often decreases at military posts during warm months in which field maneuvers are practiced; this is generally accompanied by substantial reduction in per capita loading at sewage plants. Relevant data for 44 military sewage plants operating during the period January, 1943, to September, 1944 (14), are summarized in table at top of next column.

The data would appear to warrant a conclusion that the annual average per capita loading of Arctic sewage plants may exceed that experienced in continental U. S. World War II plants by a factor of 20 to 30 per cent.

B.O.D. (lb./cap./day)		Susp. Sol. (lb./cap./day)	
Over-all Monthly Average	Minimum Monthly Average	Over-all Monthly Average	Minimum Monthly Average
0.19	0.14	0.15	0.12

Sedimentation

The influence of temperature on the performance of settling tanks has been the subject of a number of investigations. The main conclusion is that no pronounced deleterious effect of cold *per se* on efficiency is manifest. Particles settle more slowly in cold fluids because of increased viscosity. The time for a sewage particle to settle a given distance at 60° F. is increased by a factor of 40 per cent when the temperature drops to 40° F. On the other hand, particles in sewage tend to be somewhat larger and heavier during cold weather. Low temperatures affect the stability of colloids adversely and agglomeration rates are increased. In cold weather, moreover, gas-buoying of sludge particles is reduced.

It would appear that most settling tanks perform more efficiently on the whole during warm weather if maintained in aerobic condition. Schroepfer (23) concluded, from studies at the North Side plant at Chicago, that the reduction in subsidence velocities with decreased temperature more than offset other compensating factors, and settling tanks performed with reduced

efficiency during winter months. Ridenour (24) submitted data indicating that the temperature effect was not large except when detention periods were less than 30 min. Jenkins, Hewitt, and Winsor (25) were unable to find any marked relation between temperature and sedimentation basin efficiency in an extensive series of tests at the Yardley, Saltley, and Coleshill works in England.

Bacteria densities in primary settling tank effluents have been found to be higher in warm weather than in cold (26). This is probably to be attributed partly to increased die-away rates and partly to increased flocculation occurring in cold sewage. Several investigators have noted an apparent reduction in per capita coliform production in winter (summer, 4×10^{11} *E. coli* per person daily; winter, 1.33×10^{11} *E. coli* per person daily).

Trickling Filtration

Results of several investigations indicate that trickling filters generally have lower efficiencies in cold weather. Although the observed differences are not often found to be large, the problem is one of considerable importance in the design of filters for low-temperature regions. Some insight into the matter may be had from an analysis (Table I) of B.O.D. results at 9 military standard trickling filter plants during the summers (July, August, September) and winters (December, January, February) of 1943 and 1944. The efficiencies pertain to filtration and secondary settling. The summer results are adjusted (Col. 5) to take into account differences in loading that occurred during the two seasons. The data indicate a small but significant *

* On the basis of the "student t-test" and other statistical tests for significance.

TABLE I.—Effect of Temperature on B.O.D. Efficiency of Open Trickling Filter Plants

Post	Filter Loading[1] (lb. B.O.D./afd.)		B.O.D. Efficiency (%)				Average Air Temperature (° F.)		
	Winter (1)	Summer (2)	Winter[2] (3)	Summer[2] (4)	Summer Adjusted[3] (5)	Difference[4] (6)	Winter (7)	Summer (8)	Difference[5] (9)
Campbell, Ky.	358	370	91.3	90.5	90.7	− 0.6	40.2	78.4	38.2
Crowder, Mo.	338	420	89.8	88.5	90.6	+ 0.8	38.0	78.0	40.0
Fitzsimons GH, Colo.	272	374	73.5	79.6	81.0	+ 7.5	34.6	71.8	37.2
Great Lakes, Ill.	1,920	2,200	74.4	74.4	75.8	+ 1.4	—	—	—
Benj. Harrison, Ind.	298	531	86.5	86.1	89.3	+ 2.8	31.3	72.6	41.3
Sheridan, Ill.	380	227	70.0	73.6	71.2	+ 1.2	22.7	69.4	46.7
Swift, Texas	290	247	84.3	89.9	88.9	+ 4.6	49.2	81.2	32.0
Turner AAF, Ga.	214	256	89.7	86.3	87.2	− 2.5	53.6	80.5	26.9
Leonard Wood	338	372	84.5	95.0	95.7	+11.2	40.6	83.0	42.4
Average	—	—	—	—	—	2.93	—	—	38.1

[1] Based on B.O.D. in primary settling tank effluent.

[2] Includes secondary settling tanks.

[3] Col. 4 increased or decreased by an adjustment, Δy, for differences in loading, where

$$\Delta y = \frac{-0.0043 y^2 \Delta x}{100\sqrt{x}},$$

in which y is the summer B.O.D. efficiency, in per cent, and x is the B.O.D. load, in pounds per acre-foot per day. The formula was obtained by differentiating the NRC filter load formula [*Sewage Works Jour.*, 18, 5, 970 (Sept., 1946), Eq. 25].

[4] Col. 5 − Col. 3.

[5] Col. 8 − Col. 7.

drop in efficiency during the colder months. The average temperature difference between winter and summer was 38.1° F. With military sewage of the usual concentration, this difference in efficiency results in effluents with a B.O.D. about 20 per cent larger in winter than in summer. In some streams this difference is sufficient to cause anaerobic conditions. With an outfall discharging into an ice-covered river, it might have an especially undesirable effect. In this connection it is of interest to estimate the increase in volume of media of a filter that would be required in winter in order to retain summer-time efficiency. Such an estimate is made in the following computation, which is based on the filter formula developed by the NRC Subcommittee on Military Sewage Treatment (14):

$$y = \frac{100}{1 + 0.0085x^{\frac{1}{2}}}$$

in which y is the B.O.D. efficiency, in per cent, of filters and secondary settling tanks, and x is the filter loading of applied B.O.D., in pounds per acre-foot per day. If x is taken as the median value of the summer loadings (that is, 372 lb. per acre-ft. per day), then the average summer efficiency, y_s, may be calculated by substitution in the formula, thus:

$$y_s = \frac{100}{1 + 0.0085\ (372)^{\frac{1}{2}}} = 86.0\%.$$

The corresponding winter efficiency, y_w, using the average differences in Table I, would be $y_w = 86.0 - 2.93 = 83.07\%$. The B.O.D. loading, x_w, corresponding to this value may be evaluated from the relation

$$83.07 = \frac{100}{1 + 0.0085(x_w)^{\frac{1}{2}}}$$

or $x_w = 576$ lb. per acre-ft. per day.

Hence, a difference in B.O.D. efficiency of 2.93 per cent corresponds to a difference of $\frac{2(576 - 372)}{(576 + 372)}\ 100 = 43$ per cent in volume. That is, in winter the volume of a filter must be 43 per cent larger to attain the same degree of treatment it attains in summer. The Army "Engineering Manual" of the Office of the Chief of Engineers specifies that filters in the northern states be designed 25 per cent larger than in southern states. This is in line with the foregoing value when account is taken of the difference in the average annual temperatures of the two sections of the country.

Filters in the Arctic would operate at temperatures lower on the average than those analyzed, and an allowance greater than 25 per cent for temperature is therefore required. As the average annual temperature in northern Alaska is about 8° F., an allowance of the order of 50 to 60 per cent appears to be indicated.

There is, of course, the question of the economic justification for such substantial increases in volume to attain such seemingly small increases in efficiency. This is the crux of the comparison of the relative merits of the high-rate and standard trickling filters, and the former certainly serve a useful function. The last fraction of organic load is expensive to treat. Whether its removal is worth-while depends on the local situation. In some streams it may represent the difference between effective and ineffective treatment; in others it may be unimportant.

The performance of an open high-rate filter at Boras, Sweden, has been recorded by Johansson and Sonden (27). Despite temperatures that range as low as − 30° F., the plant removes 75 per cent of the B.O.D. of the sewage, which contains a considerable amount of textile waste. The operators did not observe any increase in efficiency during a period when forced ventilation was tried.

Arnold (11) submitted B.O.D. data for winter operation at the low-rate filter plant of Grafton, N. Dak. (population 5,160). This plant has a single

TABLE II.—B.O.D. Loading and Performance Data for Open and Covered Filters at Grafton, N. Dak.

Date	Sampling Point[1]	Sewage Temp. (° F.)	B.O.D. (p.p.m.)	B.O.D. Eff. (%)
2/9/47[2]	1	49.8	184	—
	2	48.2	123	33
	3	36.6	58	52
	4	43.6	48	61
6/26/47[3]	1	65.0	163	—
	2	65.6	73	55
	3	67.1	57	22
	4	66.5	45	38

[1] 1 raw sewage, 2 primary effluent, 3 open filter effluent, and 4 housed filter effluent.
[2] Flow, 0.316 m.g.d.; air temperature, 0.4° F.
[3] Flow, 0.298 m.g.d.; air temperature, 66.1° F.

clarifier (35 ft. diameter by 8 ft. deep) and two similar filters in parallel, one housed and the other open. The filters had volumes each of 0.66 acre-ft., with fixed nozzle distributors. Loading and performance data for two 24-hr. composite samples are shown in Table II.

In both samples the housed filter exhibited a superior performance. This was not invariably the case, however; 3 samples of a total of 6 collected at various times during 1947 indicated a better effluent in the open filter. The February sample is of particular interest, inasmuch as it was collected at the end of an extended period of cold weather, in which the temperature fell as low as − 25° F. During this time the surface of the open filter was largely iced over.

Arnold also analyzed B.O.D. data presented by Hunter and Cockburn (28) for the plant at Dalmarnock, Scotland, where an open and a covered filter were operated in parallel; the former had a depth of 7.5 ft., the latter 18 ft. The data indicated a greater annual B.O.D. efficiency in the covered filter, despite the fact that it was more heavily dosed. Nitrification, however, was greater in the open filter. If nitrates are considered part of the oxygen resources, the performance of the open filter compares favorably with the covered filter, as shown in Table III. The mean annual efficiency of the open

TABLE III.—B.O.D. Loading and Performance Data for Open and Covered Filters at Dalmarnock, Scotland

Date	Dosage (gal./cu. yd.)	B.O.D. (p.p.m.)			NO_3^- (p.p.m.)	Reduction[1] (%)
		Influent	Effluent	Reduction (%)		
(*a*) Covered Filter						
Jan.	253	154	53	66	trace	66
Feb.-May	169	119	33	72	0.7	74
Jun.-Jul.	233	141	25	82	11.0	98
Aug.-Sept.	395	120	27	78	7.8	91
Sept.-Nov.	440	104	28	73	2.9	79
Dec.	423	117	40	66	0.2	66
(*b*) Open Filter						
Jan.	161	154	68	56	8.0	66
Feb.-May	156	122	42	65	9.2	82
Jun.-Jul.	152	141	40	71	6.3	80
Aug.-Sept.	156	120	34	72	9.6	88
Sept.-Nov.	155	104	34	67	10.2	87
Dec.	137	117	41	65	8.9	80

[1] Based on reaction $NH_3^- + 2O_2 \rightarrow NO_3^- + H2O$.

TABLE IV.—B.O.D. Data at Four Sewage Plants in Minnesota with Enclosed Low-Rate Filters, February-March, 1929

Plant	Date	Flow (m.g.d.)	B.O.D. (p.p.m.)		Filter Loading lb. B.O.D./ acre-ft./day	Over-All Removal (%)
			Raw Sew.	Plant Effl.		
Eveleth	2/14/29	0.75	152	22	160	85
Virginia	2/15/29	1.10	404	73	630	82
Edina	2/20/29	0.058	370	90	590	76
Austin	3/8/29	1.40	205	105	323	49

filter (as measured by the B.O.D. and nitrates) was 89 per cent; that of the covered filter was 87 per cent.

A series of tests on enclosed low-rate filters during February and March, 1929, were conducted by the Minneapolis-St. Paul Metropolitan Drainage Commission (31). B.O.D. results, as based on 24-hr. composite samples collected at half-hour intervals, are summarized in Table IV. In all four plants, the sewage received primary and secondary settling. The efficiency of the Austin plant was out of line with that of the others; the difference was attributed in part to lack of proper distribution on the filter. At Edina, the effluent from the humus tank passed through a sand filter and received treatment beyond that indicated in Table IV.

Temperature data for the four plants are shown in Table V. The filter buildings in all cases were unheated.

The coli-indices (per ml.) in the plant effluents were as follows: Eveleth, 10,000; Virginia, 10,000; Edina, 1,000; and Austin, 10,000.

The investigators concluded that "The operation of the covered filters in the winter months is carried on without any deleterious effect on the condition of the bed, and without a marked impairment in the quality of the effluent produced." No ice was formed on the covered filters or in secondary settling tanks.

At Winner, S. Dak., Madison (15) found that the relative stability of the filter effluent dropped sharply from 98 to 40 per cent during storm periods, when open filters become covered with a thick ice layer. The filters sloughed considerably during these periods. The relative stability would remain low for some time and then gradually increase, only to drop again with another heavy formation of ice.

Pöpel (29) presented data for high-rate filters indicating an increase in oxygen uptake of 63 per cent with an increase in temperature from 50° to 68° F. This, however, is not a complete measure of filter efficiency, as part of the removal in filters is obtained by agglomeration of organic material that is not completely oxi-

TABLE V.—Temperature in Four Minnesota Sewage Plants with Enclosed Low-Rate Filters, February-March, 1929

Plant	Date	Flow (m.g.d.)	Temperature (° F.)						Filter Area (acres)
			Raw Sew.	Imhoff Effl.	Filter Air	Filter Effl.	Plant Effl.	Air, Outside	
Eveleth	2/14/29	0.75	45	42	38	44	44	0	0.57
Virginia	2/15/29	1.10	56	55	48	50	50	20	0.53
Edina	2/20/29	0.058	45	42	—	—	40	−10	0.046
Austin	3/8/29	1.40	50	50	44	48	48	36	0.88

dized when removed from the sewage.

Changes in the ratio of the oxidation rate to the agglomeration are much influenced by temperature. Oxidation rates are considerably reduced in cold sewage as a result of lower metabolism in the microorganisms. Efficiencies do not decrease proportionally, however. Agglomeration continues and organic material is stored in increasing volumes of films on filter media. Heukelekian (30) examined the film formation at 1-ft. and 2-ft. levels on a standard filter and a biofilter at intervals during a year. He found that films were substantially thicker in cold weather; amounts varied from 8 to 12 lb. per cu. yd. in the standard filter, and from 5 to 11 lb. per cu. yd. in the biofilter. The amount of film was proportional to the load applied. There was, however, an extended lag period in cold weather; several months were required during this period for film thickness to build up to equilibrium values. It was found that with volumetric dosages as high as 18 m.g.a.d., flushing action was not important—on the contrary, high dosages induced thick films. Unloading in the biofilter tended to be continuous and not seasonal. It did not deplete the film markedly. The film in the standard filter also increased during winter and decreased to a low level in the spring after sloughing.

It is believed that the phenomenon of storage of organic solids in films in trickling filters during cold periods is an important factor that must be taken into consideration in the design of filters for the far North. With an annual average temperature less than 10° F., it may be expected that films will continue to accumulate over periods two or three times longer than in the States. A film weight of, say 20,000 lb. per acre-ft. could theoretically store B.O.D. that was applied at the rate of 400 lb. per acre-ft. per day for a period of the order of 100 days, assuming a 1:1 oxidation-agglomeration ratio. This is about the duration of the cold-weather period in northern temperate zones. The volume of such a film at a concentration of 5 per cent solids would be about 6,400 cu. ft. per acre-ft. This volume would occupy about 30 to 40 per cent of the available void space in the media. Because periods of extended cold in the Arctic may be very much longer than 100 days, it may be expected that the filling of air interstices in the media of an Arctic filter by organic film may continue and attain a much higher degree—possibly to the extent of interfering with normal or forced ventilation, or even completely clogging the filter. It is believed that the percolating water may not be relied upon to exert a flushing action sufficient to limit the film build-up. Velocities of downward flow of fluid are not large even in a filter that is heavily dosed; except at the surface, they are less than 0.1 ft. per sec., which is hardly sufficient magnitude to cause erosion. It would appear, therefore, that film accumulation is an important factor to be considered in the design of filter plants for the far North; certainly the problems presented merit further experimental investigation.

Activated Sludge

A number of investigators have examined the effect of cold weather upon activated sludge operation. In general, it may be said that the adverse effect of cold on the performance of activated sludge plants is less than it is on trickling filter plants.

Hurley (8) presented data for a mechanical activated sludge unit operating in parallel with a trickling filter during a period of unusual cold. A summary of the results is shown in Table VI. During the period of study the load distribution between the two units remained fairly constant.

It is evident that the trickling filter plant deteriorated more in the winter

TABLE VI.—February and August Performance Data of an Activated Sludge Unit and a Trickling Filter Operated in Parallel[1]

Test	Tr. Filter		Act. Sludge	
	Summer	Winter	Summer	Winter
Ammonia	8	19	35	36
Nitrate and nitrite	31	26	0	0
B.O.D., 5-day	14	33	9	13
Suspended solids	17	36	2	8

[1] Values are for the settled final effluents, in p.p.m.

than did the activated sludge plant. The data were collected during an unusually severe winter. Normally, the plant did not show such pronounced deterioration during cold weather.

Bloodgood (32), in analyzing records at the Indianapolis plant for several years, found that lower temperatures in the aeration basins caused a reduction in the quality of the effluent unless compensating measures (such as increasing the detention time) were taken. At the Indianapolis plant, the secondary treatment units were not large enough to give complete treatment to the entire flow of sewage. The plant was operated by treating the maximum amount possible in the activated sludge units and the balance by plain aeration. The proportion of sewage routed through each unit was such as to give the best combined effluent. With applied sewages of B.O.D. concentrations ranging from 165 to 226 p.p.m., it was found that when temperatures decreased from 79° to 57° F., the detention period had to be increased about 45 per cent in order to achieve the same degree of treatment.

Sawyer (33) concluded from an investigation on the effect of temperature that higher concentrations of solids in the mixed liquor were needed at low temperatures to effect an equal degree of B.O.D. removal. He found that the rate of sludge growth was higher at low temperatures and that sludge of a higher volatile content was produced.

There would appear to be no inherent limitation in the activated sludge process that would interfere with its adaptation for use in the far North. Designs should provide for ample detention periods and for large volumes of activated sludge. Digestion facilities should be proportioned accordingly.

Sludge Digestion

The importance of temperature in the anaerobic digestion of sewage sludge is well-known and has been studied by many workers. Fair and Moore (34) found that the time required for complete digestion varies with temperature in accordance with the following schedule:

Temperature (° F.)	Digestion Time (days)
40	110
50	76
60	55
70	40
80	30
90–105	25

The relative costs of constructing, insulating, and heating of sludge digesters in the Arctic may be expected to be different from those in the States. Accordingly, it may be found that the optimum temperature for Northern digesters will not be in the 85° to 95° F. range that is common in temperate zones. It would appear that the proper design is largely a question of economics. A sufficient amount of operational data are available to anticipate with a fair degree of precision the performance of digestion tanks operated at any temperature and with any loading within reason.

Sludge Consolidation

Available data indicate that considerably longer periods are needed at low temperatures to effect a given degree of compaction of sludge than are necessary at higher temperatures. This has a bearing on the design and operation of sludge concentration tanks. Rudolfs and Logan (35) in-

vestigated the times required to compact fresh and digested sewage sludges. The initial concentrations of the fresh sludges observed ranged from 0.5 to 6.2 per cent total solids; those of the digested sludges ranged from 0.5 to 7.9 per cent. The consolidation periods to reach the same final concentration were much lower at 50° F. than at 98° F., the optimum temperature for fresh sludge. At temperatures higher than 98° F. the compaction rate of fresh sludge was somewhat reduced by gas buoying of fermenting particles.

Effect of Temperature on Self-Purification in Receiving Waters

Rates of biochemical stabilization and bacterial die-away in streams are markedly lower at near-freezing temperatures than at higher ones. This has much significance in the design of Arctic sewage plants. The organic material and bacteria in the effluent of sewage plants will persist for much greater distances and longer times in the cold streams of the North than in the warmer streams of the continental U. S. An indication of the time required in the self-purification process is given by the B.O.D. reaction-velocity constant, k, in the first-order equation

$$y = L(1 - 10^{-kt})$$

which approximately expresses the time-rate of biochemical oxidation. In this equation y is the amount of B.O.D., remaining after time, t, starting with an initial (ultimate) B.O.D., L. The reciprocal of the reaction-velocity constant, $1/k$, gives the time necessary to effect a 90 per cent reduction of the initial B.O.D. A brief summary of low-temperature B.O.D. studies by Moore (36) and Gotaas (37) is shown in Table VII.

It may be concluded that purification periods 3 to 5 times longer are required at near-freezing temperatures than at 20° C. The effect of temperature on the ultimate oxygen demand, L, is less pronounced. Gotaas found the following relation to apply approximately for temperatures between 5° and 25° C.:

$$L = L_{20}[1 + 0.00066(T - 20)]$$

where T is the temperature in ° C.

In a stream survey of the Red River of the North by the Minnesota and North Dakota State Health Departments (40), it was found that in this stream, which received a heterogeneous collection of wastes, the 5-day, 20° C. B.O.D. was equal approximately to the 30-day, 0° C. B.O.D.

Bacterial die-away rates in cold streams have been measured in several stream pollution surveys. Typical results obtained by the U.S.P.H.S. on the Illinois, Ohio, and Mississippi Rivers are shown in Table VIII.

It is evident that the temperature effect on survival is considerable. At 75 hr., for instance, the geometric mean of the ratio of the number of organisms surviving at 1° C. to the

TABLE VII.—B.O.D. Reaction Velocity Constants at 0.5°, 5°, and 20° C.

Observer	Test	Dilution Water	Reaction-Velocity Constant per Day			Lag Period (days)		
			0.5° C.	5° C.	20° C.	0.5° C.	5° C.	20° C.
Moore	Settled domestic sewage	Bicarb.	0.036	0.059	0.18	1.5	3.7	−0.2
Moore	Settled domestic sewage	Phosphate	0.037	0.051	0.12	2.6	1.0	−0.7
Moore	Aberjona Brook Water		0.012	0.017	0.026	−8.2	−8.1	−0.4
Gotaas	Cotton-filtered domestic sewage	Bicarb.	—	0.066	0.17	—	3.3	0.0
Gotaas	Cotton-filtered domestic sewage	Bicarb.	—	0.048	0.19	—	1.1	0.1

TABLE VIII.—Effects of Time and Temperature on the Removal of Coliform Bacteria in Streams

Flow Time (hr.)[1]	Per Cent of Coliform Bacteria Surviving					
	Upper Illinois		Ohio		Mississippi	
	1° C.	25° C.	1° C.	25° C.	1° C.	25° C.
0	0	0	0	0	0	0
25	53	89	70	65	70	85
50	75	95.9	88	88	81	95
75	85	98.1	93	96	86	98.9
100	90.5	99.1	95	98.7	89	99.7
150	95.3	99.8	98	99.7	94	99.9

[1] From the point of maximum bacterial density.

number at 25° C. is 5.6. That is, in a stream at a point of 75 hr. flow time from a sewage plant outfall, the coliform density at 1° C. would be over 5 times larger than the density at 25° C. It would be even larger than this if the quality of the plant effluent deteriorated during the cold period.

The die-away rates of such pathogenic bacteria as *Eberthella typhosa*, *Salmonella schottmuelleri*, and *Endamoeba histolytica* (38)(39) decrease by a factor of 2 to 3 for each 10° C. decrease in temperature.

In view of the retarding effect of low temperature on bacterial die-away, it would appear essential that at many sites facilities for chlorination be provided in Arctic sewage plants discharging into waters used for water supply.

Stream reaeration rates are lower in cold water than in warm water. Adeney found a decrease in the reoxygenation rate of about 17 per cent with each decrease of 10° C. This value applies to open streams; reaeration in ice-covered streams may be negligible.

It is evident from all of the foregoing considerations that requirements as to the degree of treatment in a sewage plant in a region where the mean temperature is less than 10° F. during a large part of the year may differ materially from those that suffice in temperate zones.

WEATHERPROOFING SEWAGE TREATMENT PLANTS

The methods of protecting sewage plants from severe cold and wind are discussed under three headings: insulation, heating, and flow control.

The importance of proper siting of sewage plants in the Arctic can hardly be over-emphasized. Marked differences in the degree of exposure of buildings to wind and cold are created by relatively minor features of topography. Local mean temperatures differ considerably at different sites in Northern areas, where long shadows are cast by the sun during a large portion of the year. The average wind velocity increases about in proportion to the cube root of the height of a structure above the mean local elevation.

A warm zone of soil and melted frost exists around heated tanks and other sewage treatment devices that are maintained in frozen ground. This zone aids in insulating against cold air. The volume of the zone varies from approximately one to two times the volume of the structure, depending on the temperature differential. During a period of extreme cold the volume of the unfrozen zone slowly

decreases—measurements show that the lag in response to new conditions is of the order of a month, as the heat capacity is large and the conductivity is small. The warm zone under and around a tank acts as a heat reservoir that effectively buffers the structure against extreme cold periods of short duration, such as are usual in the States. If the cold period is prolonged to the durations of extreme cold that occur in the Arctic, the buffering action may fail; unless the structure is well insulated and heated, it cannot continue to operate. For this reason, it cannot be inferred that a design that has been successful at say − 30° F. in the northern U. S. will perforce be satisfactory in the Arctic.

In the economical design of the various units of sewage plant, it is of key importance to strike an optimum balance between expenditure for insulation and that for heating. Relevant data include:

1. The degree-days of cold, based on the operating temperature of the unit (40° F. for a settling tank, 90° F. for a digester) rather than the conventional 65° F. used in the common definition of "degree-day."
2. The availability and feasibility of the use of different types of insulation.
3. The physical properties of the soil at the site.

In certain areas it may be desirable to protect the permafrost from destruction by using "passive construction" and insulation methods; in this situation the unit may be constructed above the ground. In other areas it may be best to employ "active methods" for construction and insulation, in which the permafrost is destroyed and subsequent freezing prevented. It is manifest that design problems vary considerably depending on the selection of "active" or "passive" methods.

Insulation

In attempting to evaluate the heating and insulation requirements for Arctic sewage plants, an examination has been made of available data relating to heat transfer coefficients for sewage, sludge, and sewage plant construction materials. In this investigation it was found that because of the influence of many variables—some known, others unknown—the heat transfer coefficients as calculated from temperature data from existing sewage works that appeared to be comparable actually exhibited marked discrepancies in magnitude. Consequently, it was necessary to resort to statistical methods to ascertain norms.

As an example illustrating the variability of heat loss data, cold-weather temperature measurements at four northern World War II military posts of about the same size and latitude are presented in the following table:

Post	State	Minimum Temperature (° F.)[1]	
		Raw Sewage	Air
Fort F. E. Warren	Wyoming	58.6	8.2
Great Lakes NTS	Illinois	64.8	9.7
Camp Edwards	Mass.	57.6	8.9
Camp Myles Standish	Mass.	40.5	9.8

[1] Reference (14). Temperatures are median values for all days during which air temperature averaged less than 15° F., January, 1943, to September, 1944.

Of particular note is the range in minimum temperatures of raw sewage for air temperatures in the range of 8° to 10° F. The difference in sewage temperature at Camp Myles Standish and Camp Edwards is especially notable in view of the short distance between these posts; part of the difference, however, may be attributed to the fact that no laundry wastes regularly entered the sewers at the former post. Among the factors causing dif-

ferences in raw sewage temperatures, the following may be listed: infiltration of ground water; length and slope of sewers; character of the surrounding soil: degree of compaction of backfill; snow cover, if any; temperature of water supply; and per capita consumption of water.

TABLE IX.—Coefficients of Thermal Conductivity for Sewage, Sludge, and Sewage Plant Construction Materials[1]

Material	*K*	*C*
(a) Fluids		
Water	4.0	—
Sewage	4.0–4.1	—
Raw sludge	4.5	—
Partly digested sludge	5.0	—
Digested sludge	5.1	—
Ice	13–17	—
(b) Solids		
Asbestos	1.48	—
Asbestos board	0.85	—
Brick masonry	5.0	—
Cement mortar	12	—
Cinder concrete	5.4	—
Concrete (typical)	12	—
Concrete blocks	0.8–1.0	—
Tile flooring	12	—
Glass wool	0.27	—
Mineral wool	0.27–0.30	—
Sawdust and shavings	0.36–0.40	—
Corkboard	0.25–0.30	—
Fiber (flexible blanket)	0.27–0.29	—
Hair felt between layers of paper	0.25	—
Kapok between layers of paper	0.24	—
Roofing:		
Asphalt composition	6–7	—
Built up; bitumen and gravel-surfaced	1.5–3	—
Plaster board, gypsum fiber concrete, 3-ply	0.5–0.6	—
Air spaces, over ¾ in. thick	1.1	—
Wood:		
California redwood, dry	0.7	—
California redwood, 16 per cent moisture	0.8	—
White pine	0.8	—
Yellow pine	1.0	—
West Coast hemlock, dry	0.74	—
West Coast hemlock, 16 per cent moisture	0.88	—
Douglas fir, dry	0.70	—
Douglas fir, 16 per cent moisture	0.87	—
Red oak, dry	1.08	—
Red oak, 16 per cent moisture	1.21	—
Soil[2,3]:		
Fine crushe quartz	—	12–16
Ottawa sand	—	10–14
Fairbanks sand	—	8.5–19
Lowell sand	—	8.5–17.5
Chena River gravel	—	9.0–13
Crushed feldspar	—	6.0–9.5
Crushed granite	—	5.5–10
Dakota sandy loam	—	6.5–19
Crushed trap rock	—	5.0–7.0
Ramsey sandy loam	—	4.5–16.5
Northway fine sand	—	4.5–9.5
Northway sand	—	4.5–8.5
Healy clay	—	4.0–11.5
Fairbanks silty loam	—	5.0–12.0
Fairbanks silt clay loam	—	5.0–9.5
Northway silt loam	—	4.0–9.0

[1] *K* in B.t.u. per hr. per sq. ft. per ° F. per in.; *C* in B.t.u. per hr. per sq. ft. per ° F.

[2] Variable, depending on mean temperature, density, and moisture.

[3] Based on investigations of the Univ. of Minnesota Experiment Station (Bulletin 28, June 1, 1949).

A summary of heat transfer data for sewage, sludge, and sewage plant construction materials is presented in Table IX. The data are given in the form of the thermal conductivity coefficient, k, that appears in the heat flow equation—

$$q = (k/x)\, A\, (T_2 - T_1)$$

in which q is the heat flow, in B.t.u. per hr.; k is the thermal conductivity, in B.t.u. per hr. per sq. ft. per ° F. per in. thickness (a property of the material itself, not of the size or shape of a particular piece of material in question); x is the thickness of the material, in inches, measured in the direction of heat flow; A is the area of the material normal to the direction of heat flow, in square feet; and T_1 and T_2 are the boundary temperatures, in ° F.

The over-all coefficient of heat transfer, C (in B.t.u. per hr. per sq. ft. per ° F.), for a compound wall of several materials (including air spaces) of thicknesses x_1, x_2, x_3, etc., may be calculated from the formula

$$C = \frac{1}{\frac{1}{K_i} + \frac{x_1}{k_1} + \frac{x_2}{k_2} + \cdots + \frac{1}{K_o}}$$

in which, in addition to symbols already defined, K_i is the inside coefficient of transfer at the air surface (= 1.6, approximately, for ordinary materials in still air), and K_o is the outside coefficient of transfer at the air surface (= 6.0, approximately, for ordinary materials in air with a velocity of 15 m.p.h.). Heat flow in the case of a compound wall may be computed from

$$q = C\, A\, (T_2 - T_1)$$

The over-all transfer coefficients for concrete tanks containing sewage or

sludge vary markedly with the moisture of the surrounding soil. Typical values are as follows:

Condition	C[1]
Concrete tank in dry soil, top covered and flush with surface	0.10
Concrete tank in dry soil, top covered with ½ of structure above ground	0.20
Concrete tank in wet soil, top covered with ½ of structure above ground	0.40–0.75
Concrete tank in wet soil, top open with ½ of structure above ground[2]	1–2.5
Housed trickling filters	0.5–2.0
Open trickling filters[2]	2.0–6.0

[1] B.t.u. per hr. per sq. ft. per ° F.
[2] Heat loss variable, depending on wind, humidity, and rate of flow.

Heating coils submerged in sewage and sludge tend to accumulate films that lessen heat transfer rates (C decreases). Typical values of the over-all transfer coefficients for common hot-water coils are as follows:

Outside Fluid	C
Water, sewage, thin supernatant	60–80
Thin sludge	30
Thick sludge	8–15

Heating coils buried in concrete walls and flooring (panel heating) have low over-all transfer coefficients, depending on the thickness of the concrete. Tests indicate C-values of 5 to 6 for 1¼-in. steel or wrought-iron pipes spaced 15 in. apart in concrete walls 12 in. in thickness.

Effect of Shape of Tanks on Heat Loss

It is evident from the heat-flow formulation that a reduction in loss may be effected by reducing the area exposed to cold air. An idea as to the relative amounts of surface area of tanks of different shapes may be had from an evaluation of their sphericity factors (surface area of a sphere of equal volume divided by the actual surface area) as follows:

Shape	Sphericity Factor
Sphere	1
Cube	0.806
1:2:4 right solid (settling tank)	0.674
1:1 cylinder (digestion tank)	0.873
1:3 cylinder (settling tank)	0.755
1:6 cylinder (high-rate filter)	0.595

The heat-maintenance problem in Arctic plants is of sufficient importance to justify some compromise between the shaping of units for efficiency in settling or in ventilation and the shaping for maximum heat conservation.

Freezing of Pipes

During an emergency or following an accident in operation, the sewage flow may be stopped and the heat supply may be cut off. Fluids in the plant will then begin to cool, drawing on the reserve of heat in the fluids themselves and in the surrounding materials. Some indication of the magnitude of the reserve of heat in pipes in the plant in exposed locations may be had from Table X. It will be noted that insulation effectively adds to the protection against freezing.

The rate of heat leakage from pipes insulated with various materials has been given by MacIntire (41). A brief summary of findings is shown in Table XI.

Freezing of Tanks

Data pertaining to rate of heat loss from water surfaces exhibit a rather wide range of magnitude, as might be expected from the number of variables involved. Harding and Willard (42) offer a value of 4 B.t.u. per hr. per sq. ft. per °F., as based on observations made in a mill pond. Birge reported a value of 4.8 for Lake Mendota during November. Others have given values ranging between 3.46 and 5.1.

The cooling of still water proceeds with the transfer of heat to the atmos-

TABLE X.—Influence of Insulation in Preventing the Freezing of Sewage in Pipes with Surrounding Air at −18° F.[1]

Pipe Diameter (in.)	Time to Cool 42° F. Sewage to Freezing Point (hr.)			Flow of Sewage at 42° F. to Prevent Freezing (c.f./100 Lineal Ft. of Pipe/hr.)		
	Thickness of Insulation (Conductivity, k_1 = 0.30)					
	2 in.	3 in.	4 in.	2 in.	3 in.	4 in.
1	0.83	1.02	1.16	1.09	0.88	0.77
2	1.94	2.48	2.90	1.52	1.20	1.03
4	4.55	6.02	7.20	2.36	1.78	1.49
6	7.35	9.88	12.20	3.18	2.34	1.91
8	10.05	13.90	17.25	3.94	2.87	2.29
10	13.00	18.10	22.70	4.74	3.40	2.72
12	15.80	22.20	28.10	5.50	3.93	3.10

[1] "Heating, Ventilating, and Air-Conditioning Guide" (1946).

phere. The upper layers of water become more dense and sink to the bottom, forcing warmer water upward. The process continues until the body of fluid becomes isothermal at 39.2° F. As the cooling progresses, the density of the upper layers is decreased; they remain at the top and are rapidly cooled to the freezing point. Freezing begins (usually at the edges of the tank) after an amount of heat equal to the latent heat of fusion (144 B.t.u. per lb.) has been abstracted. As the ice sheet is built up, the rate of heat transfer is reduced by the insulating action of the ice itself. The process may be formulated by equating the amount of heat flowing out in a short time interval, dt, to the heat of formation of an ice layer of thickness dx:

$$(k/x)(32 - T)A\ dt = \frac{1}{12} w(H)A\ dx$$

in which k is the thermal conductivity of ice (= 15 B.t.u. per hr./per sq. ft. per ° F. per in., approximately); x is the ice thickness in inches; A is the surface area of the tank, in square feet; w is the unit weight of water (=62.4 lb. per cu. ft.); H is the latent heat of fusion of water (= 144 B.t.u. per lb.); T is the air temperature, in ° F.; and t is the time in hours.

If the air temperature remains constant, the foregoing equation may be integrated to yield the following expresson for the length of time, t, to create an ice sheet of thickness x:

$$t = \frac{w\ H\ x^2}{24\ (32 - T)\ k} = \frac{25\ x^2}{32 - T}$$

Solutions of this equation are given in Table XII.

TABLE XI.—Heat Leakage from Insulated Pipes[1]

Diameter (in.)	Type of Insulation		
	Union Lith.	2 Layers Hair Felt	Corkboard
1	0.18	0.11	0.18
2	.27	.15	.24
3	.29	.19	.30
4	.37	.23	.34
5	.45	.27	.41
6	.56	.31	.44

[1] B.t.u. per hr. per lin. ft. per ° F.

TABLE XII.—Time of Formation of Ice Sheets of Various Thicknesses

Thickness (in.)	Time (hr.) at Stated Air Temperatures		
	10° F.	−10° F.	−40° F.
1	1.14	0.60	0.35
6	41	21	12.5
12	164	86	50

The conclusion that may be drawn from Table XII is that unprotected tanks should immediately be drained; destructive ice formation proceeds rapidly in the temperatures of the Arctic winter.

Heating

A substantial part of heat needed in Arctic sewage plant operation may be supplied by heating the water supply or the sewers, utilidors, and pumping stations. Indeed, in some cases this amount may be sufficiently large so that no additional heat will be needed at the sewage plant. The proportion of heat supplied in the sewer system relative to that supplied at the plant will differ at different posts, depending on local conditions, size, and per cent occupancy. Heating at the plant may be necessary during severe cold either with water supply or sewage systems that are unheated or heated insufficiently to prevent freezing at the plant, or when the heating system in the sewer fails. The objectives of plant heating are to prevent interruption or impairment of treatment by freezing or cold, damage to treatment devices by ice, and excessive ice formation in the outfall and in the vicinity of the point of discharge.

The problems associated with the heating of sludge tanks have been extensively studied; a considerable amount of information is available as to the relative merits of different schemes for heating. On the other hand, the heating of settling tanks has rarely, if ever, been necessary. It would appear that a constructive approach to the problems of heating settling tanks may be had by investigating the similarities and dissimilarities in heating the two kinds of treatment devices. The various factors and considerations are set forth in the following outline:

Maintenance of Heat in Sewage Sedimentation Tanks

I. Relation to the Heating of Sludge and Buildings.

A. Advantage in having similar or the same heating methods and equipment for sewage, sludge, and buildings—facilitates maintenance and repair; few spare parts to stock.

B. Similarity to sludge heating.

1. Basic heat transfer principles identical.
2. Construction materials nearly the same.
3. Sedimentation tanks may be insulated in same manner as sludge digestion tanks.
4. Specific heat of both sewage and sludge practically unity (however, see C 1 below).

C. Dissimilarity to sludge heating.

1. Heat transfer coefficient of sludge considerably smaller than that of of sewage because of smaller fluidity of sludge. (If two tanks identical in shape and construction are filled one with sewage and the other with sludge and heated to the same temperature and then allowed to cool, the sludge will cool more slowly than the sewage.)
2. Quiescence desirable in settling; moderate stirring helpful in sludge digestion, hence thermal currents are not objectionable.
3. High temperature (80° to 90° F.) necessary for sludge digestion; unnecessary, even detrimental, in sedimentation.

4. Heat requirements for sludge vary with stage of digestion, and temperature gradients are desirable in digesters; these would impair settling, as thermal (density) currents would be produced.
5. No gas hazard entailed in heating settling tanks.
6. Interference with biological activity (sterilization and disinfection) of no importance in heating of settling tanks.
7. Rate of addition of heat to digesters is constant; must be varied in settling tanks because of diurnal variations in flow and raw sewage temperature. Latter requires more elaborate temperature control with economical operation.
8. Distribution of heat in settling tanks influenced by sizable displacement velocity; in sludge digestion tanks displacement velocity negligible (long detention period).
9. Digesters ordinarily require heat the year around; settling tanks, even with the most severe climate, would require heat only during winter months.

II. Amount of heat required.

A. To heat incoming sewage. Factors include:

1. Temperature of raw sewage reaching plant.
2. Detention period in plant and in outfall sewer.
3. Conditions at disposal point.

B. To maintain sewage heat against losses (conduction through walls; conduction and convection through soil and ground water; radiation to exterior). Principles are same as those for head loss from sludge digestion tanks; the same heat transfer coefficients for walls and soil are applicable. Sedimentation tanks have somewhat larger surface per unit volume; this circumstance, together with the fact that sewage is less viscous than sludge, results in a more rapid rate of transfer to exterior than from sludge digesters at the same temperature gradients. Factors include:

1. Type of construction.
2. Provisions made for insulation (covers, embankments, etc.).
3. Ground water.

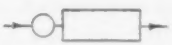
III. Methods of heating settling tanks.

A. Internal heat exchangers: hot water coils in tank.

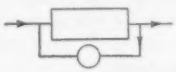
1. Types: vertical and horizontal. Vertical less prone to collect sludge and form scale, but more likely to induce high-velocity thermal currents. Accessibility is chief advantage pertaining to vertical. Coils embedded in walls do not accumulate scale or corrode on the outside, but have a lower over-all heat transfer coefficient (43)(44).
2. Advantages.
   a. Simplicity.
   b. Easy to combine with sludge digester having arrangement if common method of heating is used in latter.
   c. Scale formation less with relatively large area of coils (as compared with small area of transfer used in other heating methods).

3. Disadvantages.
   a. Temperature non-uniform in tank and thermal currents may impair settling efficiency.
   b. High local temperatures may cause sludge flotation; anaerobic biological activity may cause odors. Gases coming out of solution on and near coils may interfere with settling.
   c. Waste heat.
      (1) In flue gas from boiler.
      (2) In transmission line from boiler to digester.
   d. Settling tank out of service during repair of horizontal coils.

B. External heat exchangers.
   1. Location.
      a. On influent line.



      b. On recirculation line from tank outlet to tank inlet. When recirculated flow is heated, tank temperature may be controlled two ways: (i) by varying the rate of recirculation and (ii) by varying the temperature gradient in the exchanger. Without recirculation, only the latter method of control is available. Hence Blb and Blc afford more positive control—temperature may be maintained even when the plant inflow is low or zero.



      c. Near tank with separate suction and discharge lines. Not so satisfactory as b because of thermal currents resulting from non-uniform distribution of heat in tank.

   2. Advantages.
      a. Readily accessible for repair.
      b. Settling tank need not be taken out of service to repair heat exchanger, as it may be heated by another heat exchanger.
      c. High velocities in exchanger bring about higher heat transfer coefficients.
      d. Much developmental work has already been done on external heat exchangers for sludge heating in small plants. Commercial heaters using gas and gas-oil burners with automatic thermostatic control are available.
      e. Heat may be applied to flow in inlet pipe (Bla and Blb), avoiding sharp thermal gradients in tank that may interfere with settling. However, if inflowing fluid is considerably warmer than average temperature in the tank, it may "ride over" tank fluid directly to the outlet. Short-circuiting of this nature may result in inadequate treatment. Moreover, the lower portion of the fluid may develop objectionable odors if circulation is inadequate.

3. Disadvantages.
   a. Large temperature gradients in exchanger tend to accelerate the rate of build-up of scale.
   b. Wastes heat.
      (1) In flue gas.
      (2) In transmission to digester or settling tank.
   c. If recirculated fluid heated (Blb and Blc), then tank volumes must be increased to provide necessary detention period. (This would of course not be a disadvantage if recirculation were otherwise necessary, as in high-rate filtration.)

C. Submerged gas burners.
   1. Similar in design to types developed for sludge heating. In application to settling tank heat, no gas hazard entailed. Many problems of design have already been worked out for submerged burners in other applications (45).
   2. Advantage: 100 per cent efficient use of fuel—no losses in flue gas or in transmission.
   3. Possible disadvantage: odors caused by very high local temperatures (not a problem in the closed digester system).

D. Direct addition of hot water.
   1. Advantages.
      a. Saves cost of coils.
      b. May be added to sewage flow in a manner such that sharp temperature gradients in tank do not occur (multiple outlets).
   2. Disadvantages.
      a. Water costs may be high.
      b. Possibility for cross-connection with potable supply. (However, protection against such a cross-connection may easily be provided.)
      c. Tank would have to be made larger to handle increased flow at the requisite detention period.
      d. Dilution likely to impair sedimentation efficiency.

E. Direct addition of steam.
   1. Point of injection.
      a. On suction side of pump (if raw sewage pumped at plant); would require low-pressure, heat-type boiler.
      b. On pressure side of pump; would require high-pressure, power-type boiler. Possibility that design might utilize propelling power of steam jet.
      c. Directly into settling tank. Disadvantage: additional baffling might be necessary to prevent excessive turbulence. Advantage: uniform distribution of heat—short-circuiting possible with a and b.
   2. Advantages.
      a. Considerable experience available (California) with sludge heating by direct addition of steam. A number of design problems (for example, noise and vibration of jet) have been solved.
      b. Amount of dilution by condensate not large. (At one installation: 1 gal. condensate per 10° F. temperature rise for every 110 gal. of sludge heated.)
      c. Flexibility of operation; simplicity of installation.

d. Steam available at military posts for heating buildings and utilidors.

3. Disadvantages.
   a. Waste heat.
      (1) In flue gas.
      (2) In transmission (not, however, if routed through utilidor).
   b. High local temperatures in vicinity of jet may release gases from solution; small bubbles may interfere with settling by buoying particles to surface.

Heating Requirements of Closed Filters

The heat, H (B.t.u. per hr.), necessary to maintain the temperature drop, $T_i - T_o$ (° F.), at any desired amount in a sewage treatment device with a surface area A (sq. ft.) and an over-all heat transfer coefficient C (B.t.u. per hr. per sq. ft.), and carrying a discharge of Q (m.g.d.) may be computed approximately from the following heat balance equation:

$$H = C\,A[(1/2)\,(T_i + T_o) - T_a] - (1/24)\,(8\tfrac{1}{3})\,(10^6)\,Q\,(T_i - T_o)$$
$$= C\,A[(1/2)\,(T_i + T_o) - T_a] - 347{,}000\,Q\,(T_i - T_o) \quad (1)$$

If no heat is added to the structure, the inlet temperature may be calculated from the other quantities, if these are known, by

$$T_i = \frac{(694{,}000\,Q + C\,A)T_o - 2\,C\,A\,T_a}{694{,}000\,Q - C\,A} \quad (2)$$

Likewise, the outlet temperature may be calculated from

$$T_o = \frac{(694{,}000\,Q - C\,A)T_i + 2\,C\,A\,T_a}{694{,}000\,Q + C\,A} \quad (3)$$

if the other variables are known.

The use of the formulas is illustrated in an example pertaining to a trickling filter plant, in which no heat is supplied other than that in the sewage and that available from sludge digestion.

Sample Calculation of Heat Balance in Trickling Filter Sewage Plant Based upon Arctic Climatological Factors

I. Specifications.

Tributary population = authorized population × capacity factor
= 5,000 × 2.0 = 10,000 persons.
Sewage flow, at 70 g.c.d. = 0.70 m.g.d.
Temperature of raw sewage = 42° F.
Air temperature = −30° F.

II. Characteristics of sewage.

Suspended solids, at 0.20 lb. per cap. per day = 0.20(10,000) = 2,000 lb. per day.
B.O.D. (5-day), at 0.20 lb. per cap. per day = 0.20(10,000) = 2,000 lb. per day.
Grease, at 0.10 lb. per cap. per day = 0.10(10,000) = 1,000 lb. per day.

III. Settling tanks.

A. Primary.

Number: two (one out of service when occupancy less than design), both covered.

Detention period = 2.5 hr.
Capacity = 5,570(0.7) (2.5) = 9,750 cu. ft.
Surface area of tanks 8 ft. deep = 9,750/8 = 1,220 sq. ft.
Length of two rectangular tanks 10 ft. wide = 1,220/20 = 61 ft.

B. Secondary tanks.
Same as primary.

IV. Trickling filters.
Number: two, covered, in parallel, no recirculation.
Filter dimensions: 70-ft. diam., 6-ft. depth.
Total volume = (2) $(\pi/4)$ $(70)^2$ (6) ÷ 43,560 = 1.06 acre-ft.
B.O.D. loading (see reference (14), page 968), assuming 30 per cent B.O.D. removal in primary tanks, $= \frac{2{,}000\ (1.00-0.30)}{(1.06)} = 1{,}320$ lb. per acre-ft.
In using filter performance formulation (14), assume that because of colder temperature the filter volume is 2/3 as effective as it would be in the continental U. S.
Effective loading = (3/2) (1,320) = 1,980 lb./acre-ft.
Filter efficiency for this load = 72.5 per cent.
Weight of B.O.D. in effluent = 2,000 (1.00–0.30) (1–0.725) = 385 lb. per day.
B.O.D. concentration in effluent = 385/(8⅓) (0.7) = 66 p.p.m.
Over-all plant removal = 100(2,000–385)/2,000 = 80.8 per cent.

V. Sludge digestion tanks.
Tank temperature: 90° F.
Total solids at 1,500 lb. per m.g. sewage = 1,500(0.7) = 1,050 lb. per day.
Capacity at 3.0 cu. ft. per cap. (primary digester only) = 3.0 × 10,000 = 30,000 cu. ft.
Diameter of tank 30 ft. deep $= \sqrt{\frac{4}{\pi}\frac{(30{,}000)}{30}} = 36$ ft.
Two additional storage digesters heated by supernatant flow bring total capacity to 90,000 cu. ft. Alternate scheme: winter storage lagoons.

VI. Heat losses—critical month.
Average sewage temperature = 42° F.
Air temperature = −30° F.
Surface areas:

1. Primary settling tanks.
   Total surface area = 2 $[(20\times61)+(8\times20)+(8\times61)]$ = 3,740 sq. ft.
   Add 60 per cent for pretreatment units and housing = 2,240 sq. ft.
   Total = 5,980 sq. ft.
2. Filters.
   Average distance from roof to top of media = 12 ft.
   $2[(\pi)(70)(12+6)+2(\pi/4)(70)^2] = 23{,}300$ sq. ft.
3. Secondary settling tanks.
   Add 30 per cent for housing = (1.3)(3,740) = 4,850 sq. ft.
4. Digester
   $[(\pi)(36)(30)+(2)(\pi/4)(36)^2] = 5{,}430$ sq. ft.

Temperature of primary settling tank effluent. Assume $C = 0.50$ B.t.u. per hr. per sq. ft. From Eq. 3,

$$T_e = \frac{[694{,}000(0.7)-(0.5)(5{,}980)]\,42+2(0.5)(5{,}980)(-30)}{(0.7)(694{,}000)+(0.5)(5{,}980)} = 41.12° \text{ F.}$$

Temperature of filter effluent. Assume $C = 0.60$ B.t.u. per hr. per sq. ft. From Eq. 3,

$$T_e = \frac{[694{,}000(0.7) - (0.6)(23{,}300)](41.12) + 2(0.6)(23{,}300)(-30)}{(0.7)\,(694{,}000) + (0.6)(23{,}300)} = 37.21° \text{ F}$$

Temperature of secondary settling tank effluent. Assume $C = 0.50$ B.t.u. per hr. per sq. ft. From Eq. 3,

$$T_e = \frac{[694{,}000(0.7) - (0.5)(4{,}850)](37.21) + 2(0.5)(4{,}850)(-30)}{(0.7)(694{,}000) + (0.5)(4{,}850)} = 36.54° \text{ F.}$$

This would leave $\frac{700{,}000}{24}(8\frac{1}{3})(36.54 - 32) = 1.1 \times 10^6$ B.t.u. per hr. for the outfall.

Required heat for digesters. Assume $C = 0.50$ B.t.u. per hr. per sq. ft.
Amount of sludge at 7,000 gal. per m.g. sewage = 4,900 gal. per day
Raw sludge temperature = 42° F.
Supernatant temperature = 90° F.
Heat to maintain digester at 90° + Heat to raise sludge temperature from 42° F. to 90° F. $= 0.50(5{,}430)[90-(-30)]-347{,}000(0.0049)(42-90)$
$= 325{,}000+81{,}600 = 407{,}000$ B.t.u. per hr.
$= 9{,}800{,}000$ B.t.u. per day.

Available heat from sludge digestion. Assume 1.0 cu. ft. gas per cap. per day, at 70 per cent methane, and 896 B.t.u. per cu. ft. for methane:

Available heat = $(1.0)(10{,}000)(0.70)(896) = 6{,}300{,}000$ B.t.u. per day.

Net heat to be supplied.

$$(9.8 - 6.3)\ 10^6 = 3{,}500{,}000 \text{ B.t.u. per day.}$$

It would appear that with covered and well-insulated tanks and high-rate filters, no heat normally need be supplied to sewage plant units other than digesters. However, a similar calculation for a standard-rate filter indicates a considerably more unfavorable heat balance because of the larger exposed area. In instances where the water supply and the sewers are not maintained at a sufficiently high temperature or where a difficult condition exists along the outfall sewer or at the discharge point, heating at the sewage plant will be required. Nevertheless, in view of the narrow margin of safety, provision should be made in all Arctic plants for emergency heating of plant units.

Heat Conservation by Flow Control

Heat may be conserved or used more efficiently by the following methods:

1. By taking treatment units out of service during periods of low flow. By providing multiple units, long detention periods in tanks may be prevented during periods of low post occupancy. Tanks should be designed so that they may be quickly drained.

2. By recirculating flow from plant effluent to influent. This maintains motion during periods of low flow and tends to distribute heat more uniformly.

3. By providing for siphonically controlled flow.

SUMMARY AND RECOMMENDATIONS

Foremost among the various considerations that are important in the design of sewage treatment plants in the far North are the following:

1. Plant units should be designed in replicate wherever possible. By retaining the proper number of units of each type in service, prolonged detention periods that increase freezing hazards may be avoided.
2. All major plant units should be covered or housed.
3. Tanks should be designed so that they may be rapidly and completely drained.
4. Provision should be made for emergency heating of important treatment devices.
5. The capacities of tanks and filters should be determined with due regard to the adverse effect of low temperatures upon treatment efficiencies and upon the rate of self-purification in receiving waters.

Additional investigation and research are desirable:

1. In establishing the loading-performance relation for trickling filters operating for long periods (8 or more months) at temperatures just above freezing.
2. In determining efficient methods of heating settling tanks so as to avoid density currents and degasification; in particular, the development of a portable, inexpensive type of heater that may be applied to settling tanks would appear to be indicated.
3. In ascertaining the extent to which odor and corrosion will be increased in sewage works involving insulated heated sewers, enclosed ejector pumps, and covered tanks and filters; and in developing methods of dealing with the effects of reduced ventilation, including reduced treatability of sewage.

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HYDRAULIC BEHAVIOR OF STORM-WATER INLETS

I. FLOW INTO GUTTER INLETS IN A STRAIGHT GUTTER WITHOUT DEPRESSION

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This is the first of a series of articles on model and field studies of the hydraulics of storm drain inlets. The present article deals only with model studies of gutter inlets without depressions. Investigation of the behavior of curb-openings and other inlets with various types and amounts of gutter depression is now under way and will be extended to cover the possible ways in which the inlet capacity might be increased by use of deflectors, curb setbacks, separation of curb inlet from gutter inlet, and by other reasonably promising schemes.

The research is sponsored by Baltimore City, Baltimore County, and the Maryland State Roads Commission. The Institute of Cooperative Research of The Johns Hopkins University is doing the work under the direction of the Department of Sanitary Engineering assisted by the Department of Civil Engineering.

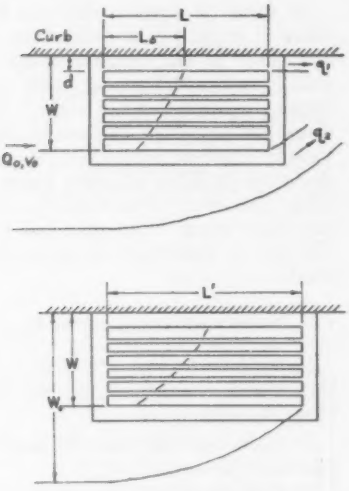
In planning the work it has been considered desirable to progress from the simpler problems to the more complex. Gutter inlets without depressions have, therefore, been studied first, even though they are not frequently encountered in the local municipal drainage systems. The danger and inconvenience to traffic of gutter depressions has already resulted in abandoning their use in modern high-speed highways. The need for providing free flow of traffic on congested urban streets is resulting in much fuller use of outside lanes, particularly on one-way streets. This trend toward use of the full width of streets for moving traffic may result in an increasing use of undepressed inlets in cities. The work on inlets without depressions presented here may, therefore, prove to be more useful than might at first be anticipated.

Apparatus and Procedure

The tests reported here were conducted on a gutter model 20 ft. long and 3 ft. wide. The model was built of wood and painted. It was suspended with threaded bolts from a frame so as to facilitate changes in street grade and crown. The upstream end of the model was connected to a head tank, to which water was supplied from a centrifugal pump. Inlet models were installed at about 12 ft. from the upstream end of the gutter model. In this arrangement, the approaching flow had ample opportunity to acquire a uniform state.

The quantity of gutter flow was measured with a venturi meter. The carryover flow (that is, the portion of the flow that did not go into the inlet) was collected in a tank and measured with a calibrated triangular-notch weir. The difference between these two measurements gave the discharge into the inlet. The depth of gutter flow was measured with a point gage equipped with an electronic device to assist in determining the mean surface elevation of the rapidly vibrating water surface.

Inlet models of 1:2 scale were used. Tests were conducted with grades varying from 0.5 to 6.0 per cent, and crowns of 1 and 0.5 in. per ft. At each



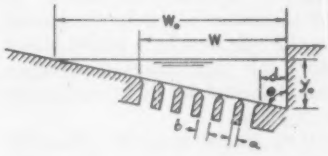


FIGURE 1 GRATES WITH LONGITUDINAL BARS

(STRAIGHT GUTTER CROSS-SLOPE DEFINED BY ANGLE θ)

grade and crown, the inlet discharges for different quantities of gutter flow were observed. For each type of inlet tests were repeated with different lengths of inlet.

Letter Symbols

The symbols used in the following discussion are:

Q_o = quantity of gutter flow (c.f.s.).
Q = discharge into the inlet (c.f.s.).
q = carry-over discharge past the inlet (c.f.s.).
q_1 = carry-over between the curb and the grate (c.f.s.) (see Figure 1).
q_2 = carry-over outside the grate (c.f.s.) (see Figure 1).
L = length of inlet (ft.).
L_o = length of grate required to capture all the flow over the grate (ft.).
L' = length of grate required to capture the outer portion of flow (ft.) (see Figure 1).

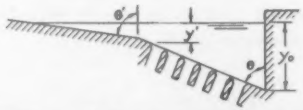


FIGURE 2.—Gutter of changing cross-slope.

d = distance between the curb and the first grate opening (ft.) (see Figure 1).
w = width of grate (ft.) (see Figure 1).
w_o = width of gutter flow (ft.).
y_o = depth of gutter flow at curb (ft.).
y' = depth of gutter flow at outer edge of grate (ft.) (see Figure 2).
v_o = mean velocity of gutter flow (ft. per sec.).
θ_o and θ' = angle between cross-section of street and vertical (see Figure 3).

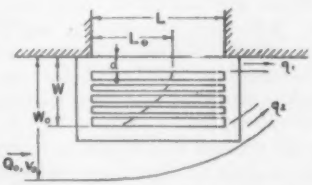


FIGURE 3.—Combination inlet with grate with longitudinal bars.

n = Manning's roughness coefficient for gutter.
s = street grade (ft. per ft.).
g = gravitational force per unit mass (gravitational acceleration) (ft. per sec. per sec.).

Other symbols used are defined where they first appear.

Method of Investigation

Due to the complex nature of the problem, it appears impossible at present to obtain a purely theoretical solution for the flow into gutter inlets. Therefore, an experimental approach has been followed by all investigators of this problem.

A review of the available literature shows that previous investigations may be grouped into two categories. The first of these constitutes calibration of a given inlet. The results of tests of this class are only valid for the particular type and size of inlet under consideration. The usefulness of these calibration data is, therefore, very limited. In the second category are attempts to obtain some rational formulas relating the capacity of the inlet to the characteristics of the gutter flow and the size of the inlet. In this approach, some assumptions have to be made, and the effects of some physical variables are necessarily neglected in order to obtain a reasonably simple equation. This approach serves a useful purpose in furnishing approximate formulas for practical use. However, where the effects of important variables have been neglected, the results can be applied with confidence only when the field conditions are similar to those of the tests. A formula obtained by neglecting the effect of the crown of the street, for instance, is only good for cases where the street has the same crown as that of the model.

In the present investigation, dimensional analysis (1) has been employed to guide the experimental work on the model. All physical variables that may affect the capacity of an inlet are included in the investigation. No assumption is made and no physical variables are neglected unless tests show that they can be neglected throughout the range of field conditions that may be encountered in practice.

In order to demonstrate the feasibility of model studies, nine tests were conducted in the field on inlets with grates and curb-opening, and reproduced, ⅓ in scale, on the model. In all cases, the prototype and model results were in excellent agreement, the mean deviation in inlet capacity being less than 1 per cent. It is believed, therefore, that storm drain inlet models of 1:3 scale or larger will produce reliable results.

Grates with Longitudinal Bars

In grate inlets with longitudinal bars (see Figure 1), carry-over may occur in three ways:

1. Flow past the inlet between the curb and the first slot, q_1.
2. Flow outside the last slot, q_2.
3. Carry-over across the grate itself.

The minimum length of inlet required to capture all the central portion of the flow over the grate itself (that is, to reduce item 3 to zero) was investigated first. The behavior of flow along the curb and outside the inlet was then studied.

Minimum Length Required to Trap Central Portion of Flow

The minimum length, L_0, required to trap the central portion of the flow depends on the approaching velocity, v_0; the depth of flow over the first opening, which is approximately equal to y_0; the width of the openings, a; the width of the bars, b; and the acting force, g.

The bars in the model were rounded off at the top. The depth and width of the model bars were equivalent to dimensions of 3 in. and 1.25 in., respectively, in the prototype.

The six quantities above give four dimensionless terms—

$$\frac{L_0}{v_0}\sqrt{\frac{g}{y_0}},\ \frac{v_0}{\sqrt{g\,y_0}},\ \frac{a}{b},\ \text{and}\ \frac{y_0}{a}$$

Thus,

$$\frac{L_0}{v_0}\sqrt{\frac{g}{y_0}} = \phi\left(\frac{v_0}{\sqrt{g\,y_0}}, \frac{a}{b}, \frac{y_0}{a}\right)$$

Tests were conducted with $v_0/\sqrt{g\,y_0}$ running up to 3; a/b equal to 1, 6/5, and 7/5; and y_0/a ranging from 2/3 to 2. It was found that for all these cases

$$\frac{L_0}{v_0}\sqrt{\frac{g}{y_0}} = m \qquad (1)$$

where $m = 4$.

Eq. 1 gives L_0 for cases where a/b lies within the range of 1 to 7/5. For cases where a/b is much larger than 7/5 (for example, grates with thin steel ribs) L_0 would undoubtedly be much less than that given by Eq. 1 with $m = 4$. However, because the actual length of the grate openings for negligible carry-over flow is ordinarily governed by other requirements (see Eq. 3 below), and is usually larger than L_0 given by Eq. 1 with $m = 4$. Eq. 1 does not control the design of grates for inlets that will intercept a reasonably large portion of the gutter flow.

When transverse bars are used for structural purposes, water striking them will jump the grate and L_0 needs to be larger than that given by Eq. 1 with $m = 4$. For example, if three bars are put at the quarter points, a value of $m = 8$ seems to be appropriate.

Carry-Over along Curb

The carry-over along the curb, q_1, depends on the approaching velocity, v_0; the depth, y_0; the length of openings, L; the width, d (see Figure 1); and the acting force, g. These six quantities give four dimensionless terms—

$$\frac{q_1}{v_0\,y_0\,d}, \frac{v_0}{\sqrt{g\,y_0}}, \frac{y_0}{d}, \text{ and } \frac{L}{d}.$$

Thus,

$$\frac{q_1}{v_0\,y_0\,d} = \phi\left(\frac{v_0}{\sqrt{g\,y_0}}, \frac{y_0}{d}, \frac{L}{d}\right)$$

Tests were conducted with $v_0/\sqrt{g\,y_0}$ running up to 4, y_0/d ranging from 1 to 2, and L/d ranging from 5 to 20. From the experimental data, the following relationship has been obtained:

$$\frac{q_1}{v_0\,y_0\,d} = 6\,\frac{v_0}{\sqrt{g\,y_0}}\left(\frac{d}{L}\right)^2 \qquad (2)$$

For grates generally used, q_1 is negligible under practically all field conditions.

Minimum Length Required to Trap Portion of Flow Outside Grate

When the width of the gutter flow, w_0, is larger than the inlet width, w, and it is desired to have $q_2 = 0$ (see Figure 1), it is necessary to have an inlet length equal to or greater than L'.

The length L' depends on the approaching velocity, v_0; the depth of flow, y_0; the gutter angle, θ_0; the inlet width, w; and the acting force, g. These six quantities give four dimensionless terms—

$$\frac{L'}{y_0}, \frac{v_0}{\sqrt{g\,y_0}}, \frac{w}{y_0\tan\theta_0}, \text{ and } \theta_0.$$

Thus,

$$\frac{L'}{y_0} = \phi\left(\frac{v_0}{\sqrt{g\,y_0}}, \frac{w}{y_0\tan\theta_0}, \theta_0\right)$$

Tests were conducted with $v_0/\sqrt{g\,y_0}$ running up to 3.5; $w/(y_0\tan\theta_0)$ ranging from 1/2 to 4/5; and $\tan\theta_0$ equal to 12 and 24. It has been found that

$$\frac{L'}{y_0} = 1.2\,\frac{v_0}{\sqrt{g\,y_0}}\sqrt{1 - \frac{w}{y_0\tan\theta_0}}\,\tan\theta_0$$

or

$$\frac{L'}{v_0}\sqrt{\frac{g}{y_0 - \dfrac{w}{\tan\theta_0}}} = 1.2\,\tan\theta_0 \qquad (3)$$

Eq. 3 has been obtained from cases where the cross-slope of the street is uniform near the inlet, as shown in Figure 1. In the case where the cross-slope changes beyond the inlet, as

shown in Figure 2, Eq. 3 should be modified as follows:

$$\frac{L'}{v_0}\sqrt{\frac{g}{y'}} = 1.2 \tan\theta' \qquad (3a)$$

where y' is the depth of flow at the outer edge of the grate. The presence of a few transverse bars in the grate has little affect on the flow coming in along the outside edge.

Gutter Carry-Over When $L < L'$

The quantity q_2 depends on the length of openings, L; the value of L' determined from Eq. 3; the width of grate, w; the approaching velocity, v_0; the depth of flow, y_0; the gutter angle, θ_0; and the acting force, g (See Figure 1). By dimensional analysis,

$$\frac{q_2}{(L' - L)\, y_0\sqrt{g\, y_0}} = \phi\left(\frac{v_0}{\sqrt{g\, y_0}}, \frac{w}{y_0 \tan\theta_0}, \frac{y_0}{L'}, \frac{L'}{L}, \theta_0\right)$$

Data from tests, with $v_0/\sqrt{g\, y_0}$ running up to 3; $w/(y_0 \tan\theta_0)$ ranging from 1/2 to 4/5; L'/L ranging from 1 to 3; and $\tan\theta_0$ equal to 12 and 24, show that

$$\frac{q_2}{(L' - L)\, y_0\sqrt{g\, y_0}} = \frac{1}{4}\left(1 - \frac{w}{y_0 \tan\theta_0}\right)^{3/2}$$

or

$$q_2 = \frac{1}{4}(L' - L)\sqrt{g}\left(y_0 - \frac{w}{\tan\theta_0}\right)^{3/2} \qquad (4)$$

In the case where the cross-slope changes outside the grate, as shown in Figure 2, Eq. 4 should be modified as follows:

$$q_2 = \frac{(L' - L)\, y'\sqrt{g\, y'}}{4} \qquad (4a)$$

where L' is given by Eq. 3a.

Table I gives the test data for grates with longitudinal bars at $\tan\theta_0 = 12$. It can be seen that the values of Q computed from Eqs. 2, 3, and 4 are very close to the values observed.

As the equations developed here have been obtained from cases where $v_0/\sqrt{g\, y_0}$ is as high as 3 or 4, they can be applied with confidence for cases where $\frac{\sqrt{s}}{n}$ is as high as 22 or more. It will be shown later that $v_0/\sqrt{g\, y_0} \leqq 0.14\, \frac{\sqrt{s}}{n}$.

Grates with Longitudinal Bars Combined with Curb-Opening

For grates with longitudinal bars combined with a curb-opening (see Figure 3), tests were conducted in the same manner as described above for the grates alone. The data show that in inlets without depression the curb-opening has little effect on the capacity. In fact, Eqs. 3, 3a, 4, and 4a can be applied without modification. Eqs. 1 and 2 become

$$\frac{L_0}{v_0}\sqrt{\frac{g}{y_0}} = 3.3 \qquad (1a)$$

and

$$\frac{q_1}{y_0\, y_0\, d} = 4\,\frac{v_0}{\sqrt{g\, y_0}}\left(\frac{d}{L}\right)^2 \qquad (2a)$$

Grates with Transverse Bars

Because tests on grates with transverse bars and no depression indicated they have very low capacity, the test data have not been analyzed. This type of inlet with local depressions is to be investigated when studying the behavior of depressed inlets.

Graphs for Office Use

In order to convert the results of this investigation into a form convenient for office use, it has been assumed that Manning's formula for open-channel flow is applicable to gutters. Manning's formula is:

$$Q_0 = \frac{1.5\sqrt{s}}{n} A_0 R_0^{2/3}$$

When the cross-slope at the gutter is

TABLE I.—Data on Grate Inlet with Longitudinal Bars (Crown = 1 In. per Ft.)[1,2,3]

Slope (ft./ft.)	Observed Data				Computed Values		
	Depth, y_0 (ft.)	Gutter Flow, Q_0 (c.f.s.)	Length, L (ft.)	Capacity, Q (c.f.s.)	v_0 (ft./sec.)	L' (ft.)	Q (c.f.s.)
0.06	0.129	0.872	2.918	0.867	8.73	—	0.860
	0.193	2.06	4.060	2.05	9.22	5.06	2.04
0.05	0.145	0.890	1.896 2.918	0.863 0.881	7.05	—	0.870 0.881
	0.189	1.46	2.560 3.542	1.44 1.45	6.81	3.60	1.44 1.45
	0.255	2.01	3.720 5.164	1.98 2.01	7.25	4.82	1.98 2.01
0.04	0.151	0.761	2.082 2.886	0.745 0.753	5.56	0.94	0.750 0.755
	0.191	1.38	1.992 2.342 3.460	1.33 1.35 1.37	6.30	3.46	1.34 1.35 1.37
	0.227	2.05	2.240 3.804 5.406	1.93 1.99 2.04	6.63	4.78	1.95 2.01 2.04
0.03	0.153	0.725	2.334 3.460	0.717 0.723	5.17	1.08	0.717 0.722
	0.201	1.342	1.960 3.460	1.305 1.340	5.55	3.32	1.305 1.340
	0.243	2.04	1.960 3.728 5.406	1.86 1.95 2.02	5.76	4.54	1.91 2.00 2.03

[1] Dimensions of prototype: $w = 1.765$ ft., $d = 0.152$ ft., bar width = 1.25 in., bar depth = 3 in., clearance between bars = 1.5 in.

[2] Model scale = 1:2.

[3] Listed values are for prototype, for cases $\frac{L}{v_0}\sqrt{\frac{g}{y_0}} > 4$.

uniform and is defined by $\tan\theta_0$ (see Figure 1), Manning's formula may be rewritten:

$$y_0 = 1.326\,\frac{(1+\sec\theta_0)^{1/4}}{(\tan\theta_0)^{5/8}}\left(\frac{Q_0}{\sqrt{s}/n}\right)^{3/8} \qquad (5)$$

or

$$v_0 = \frac{2Q_0}{y_0^2\tan\theta_0} = 1.14\,\frac{(\tan\theta_0)^{1/4}}{(1+\sec\theta_0)^{1/2}}\left(\frac{\sqrt{s}}{n}\right)^{3/4} Q_0^{1/4} \qquad (6)$$

and

$$\frac{v_0}{\sqrt{g\,y_0}} = 0.173\,\frac{(\tan\theta_0)^{9/16}}{(1+\sec\theta_0)^{5/8}}\,Q_0^{1/16}\left(\frac{\sqrt{s}}{n}\right)^{15/16} \leqq 0.14\,Q_0^{1/16}\left(\frac{\sqrt{s}}{n}\right)^{15/16} \leqq 0.14\,\frac{\sqrt{s}}{n} \qquad (7)$$

Figure 4 has been prepared for the solution of Eq. 5 for y_0. The width of the gutter flow, w_0, is also indicated.

TABLE I.—Data on Grate Inlet with Longitudinal Bars (Crown = 1 In. per Ft.)—Continued

Slope (ft./ft.)	Observed Data				Computed Values		
	Depth, y_0 (ft.)	Gutter Flow, Q_0 (c.f.s.)	Length, L (ft.)	Capacity, Q (c.f.s.)	v_0 (ft./sec.)	L' (ft.)	Q (c.f.s.)
0.02	.157	.560	1.376 1.876	.529 .552	3.79	1.04	0.548 0.554
	.195	.991	1.418 1.572 1.700	.966 .972 .974	4.35	2.44	0.961 0.967 0.970
	.219	1.43	2.020 3.916	1.39 1.42	4.97	3.40	1.38 1.42
	0.263	2.06	1.876 2.842 5.410	1.86 1.93 2.06	4.96	4.34	1.92 1.98 2.06
0.01	0.151	0.459	1.574 2.416	0.450 0.455	3.36	0.58	0.451 0.455
	0.179	0.765	1.376	0.750	3.98	1.82	0.748
	0.209	1.080	1.624 2.362	1.053 1.074	4.13	2.62	1.049 1.070
	0.243	1.52	1.960 2.460 3.680	1.46 1.49 1.52	4.30	3.40	1.46 1.48 1.52
	0.273	2.04	2.416 3.040 4.710	1.92 1.96 2.04	4.56	4.14	1.93 1.97 2.04
0.005	0.135	0.331	1.146 1.500	0.323 0.328	3.03	—	0.322 0.326
	0.171	0.577	1.062	0.563	3.29	1.30	0.562
	0.223	0.904	1.084 1.530 2.280	0.852 0.888 0.903	3.03	3.14	0.859 0.880 0.902
	0.227	1.260	2.280 3.362	1.235 1.259	4.08	2.94	1.230 1.254
	0.251	1.70	2.280 4.334	1.60 1.70	4.50	3.69	1.62 1.70
	0.269	2.08	2.500 5.104	1.90 2.08	4.79	4.26	1.96 2.08

It is apparent that, if w_0 is limited to, say, 4 ft. when values of $\tan\theta_0$ are 12 and 24, the value of $\frac{Q_0}{\sqrt{s}/n}$ should not be greater than 0.29 and 0.093, respectively. For a given gutter, if the width of flow is limited to a certain value, a limit is also placed on the gutter capacity, Q_0.

Design of Grate with Longitudinal Bars

When the cross-slope of the gutter is straight within the width of the gutter flow (see Figure 1), the required length

of a grate with longitudinal bars may be determined from Eqs. 1 and 3. In order to capture all the water flowing over the grate, it is required that

$$L \geq L_o = m\, v_0 \sqrt{\frac{y_0}{g}}$$

where, in the case of cast-iron grates, $m = 4$ if no transverse bar is used, and $m = 8$ if a few transverse bars are used for bracing. In order to capture all the water flowing outside the grate, it is required that

$$L \geq L' = \frac{1.2 v_0 \tan\theta_0}{\sqrt{g}} \sqrt{y_0 - \frac{w}{\tan\theta_0}}$$

or, combining the expression with Eq. 6,

$$L \geq L' = M\, Q_0^{1/4} \sqrt{y_0 - \frac{w}{\tan\theta_0}} \quad (9)$$

in which

$$M = 0.24 \frac{(\tan\theta_0)^{5/4}}{(1 + \sec\theta_0)^{1/2}} \left(\frac{\sqrt{s}}{n}\right)^{3/4}$$

Eq. 9 may also be written

$$L \geq L' = \frac{M\, Q_0^{1/4}}{(\tan\theta_0)^{1/2}} \sqrt{w_0 - w} \quad (10)$$

Figure 5 has been prepared for the determination of M. The value of y_0 can be obtained from Figure 4. It is

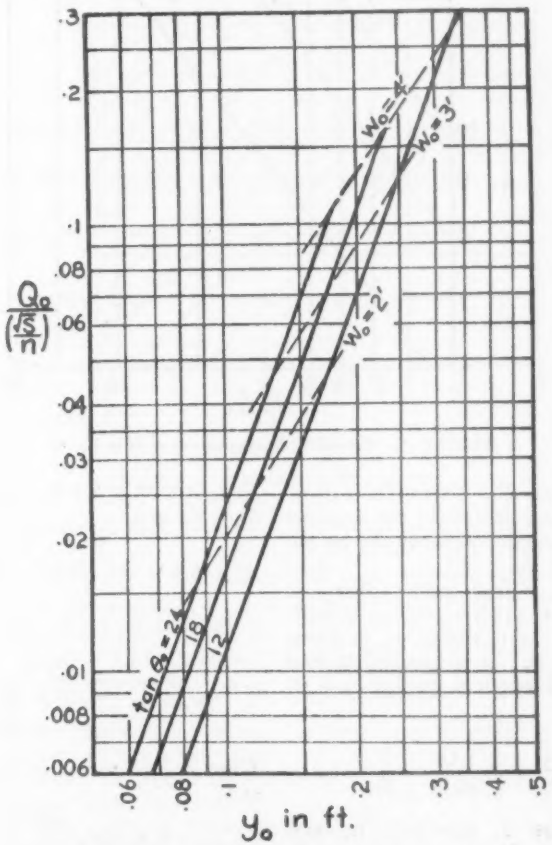


FIGURE 4.—Curves for solution of Eq. 5.

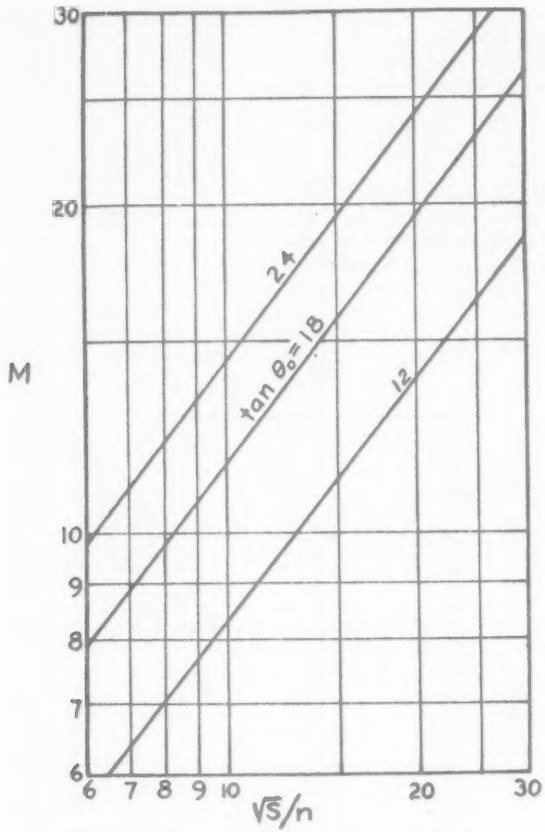


FIGURE 5.—Curves for finding values of M in Eq. 9.

apparent from Eq. 9 that, for a given condition of gutter flow, the required length of the grate depends also on the grate width, w.

Example: Given gutter flow = 2 c.f.s., street grade = 4%, $n = 0.02$, $\tan\theta_0 = 12$, and width of cast-iron grate = 1.5 ft. It is required to find the required length of grate to trap all the water.

$$\frac{\sqrt{s}}{n} = \frac{\sqrt{0.04}}{0.02} = 10, \frac{Q_0}{\sqrt{s}/n} = \frac{2}{10} = 0.2.$$

From Figure 1, $y_0 = 0.29$ ft. and $w_0 = 3.5$ ft. If the cross-slope is straight within 3.5 ft., from Figure 5 $M = 8.3$ and

$$L' = 8.3 \times 2^{1/4} \sqrt{0.29 - \frac{1.5}{12}} = 3.0 \text{ ft.}$$

To check for L_0: Since $y_0 = 0.29$ ft.,

$$v_0 = \frac{2\,Q_0}{y_0^2 \tan\theta_0} = \frac{2 \times 2}{0.29^2 \times 12} = 3.9 \text{ ft. per sec.}$$

When no transverse bar is used, $m = 4$ and

$$L_0 = 4 \times 3.9 \sqrt{\frac{0.29}{32.2}} = 1.48 \text{ ft.}$$

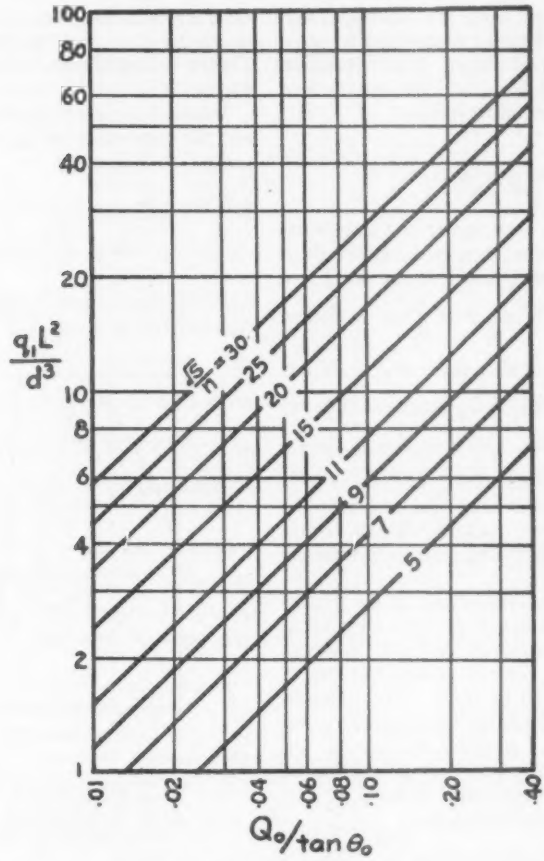


FIGURE 6.—Curves for carry-over flow.

When a few transverse bars are used, $m = 8$ and

$$L_o = \frac{8}{4} \times 1.48 = 2.96 \text{ ft.}$$

Therefore, a length of 3.0 ft. is enough to meet the two requirements.

Because the required length, L, depends also on the chosen grate width, w, it is of interest to know what value of w should be used. It can be shown that long narrow grates are just as good as short wide grates of the same total grate area. In fact, as long as the width of grate is less than two-thirds of the width of gutter flow, w_o, the total required grate area, $w\,L$, decreases as w becomes smaller. This can be shown as follows:

As long as $L > L_o$, the required length of grate, L, is governed by Eq. 9. Therefore,

Required area of grate

$$= w\,L = M\,Q_o^{1/4}\,w\sqrt{y_o - \frac{w}{\tan\theta_o}}$$

For a given gutter flow, the quantities

M, Q_0, y_0, and $\tan\theta_0$ are constants, and the required grate area depends on w only. Differentiating this expression with respect to w, and setting the first derivative equal to zero,

$$w = \frac{2}{3} y_0 \tan\theta_0 = \frac{2}{3} w_0$$

This value of w gives the maximum required grate area, $w\,L$, although L itself increases with decrease in w (see Eq. 10). With $w < \frac{2}{3} w_0$, a longer grate is required than for $w \geq \frac{2}{3} w_0$, but the grate area, $w\,L$, decreases as w becomes smaller. With $w > \frac{2}{3} w_0$ the required length is less, but there is a danger that the length may become less than required by Eq. 1. It seems, therefore, that long narrow grates are preferable.

When the cross-slope of the gutter changes outside the grate (see Figure 2) the principle of grate design is the same, except that, instead of Eq. 3 or Eq. 9, Eq. 3a should be used. The required length, L, is greater than both L_0 given by Eq. 1 and L' given by Eq. 3a. In this case, the value of y_0 cannot be determined by using Figure 4, but must be solved for by trial.

Performance of Grate with Longitudinal Bars

For a given grate, the discharge into the inlet depends on the gutter condition, as well as the gutter flow. As long as the value of L_0 given by Eq. 1 is less than the length of the grate, the carry-over, q $(= q_1 + q_2)$, is given by Eq. 2 and Eq. 4 or 4a.

Thus, when $L > L_0$ obtained from Eq. 1, and the cross-slope of the gutter is straight (see Figure 1),

$$q = q_1 + q_2$$

$$= q_1 + \frac{1}{4}(L' - L)\sqrt{g}\left(y_0 - \frac{w}{\tan\theta_0}\right)^{3/2}$$

where q_1 can be obtained from Eq. 2 or Figure 6, y_0 can be obtained from Figure 4, and L' can be obtained from Figure 5.

When $L > L_0$ obtained from Eq. 1, and the cross-slope changes outside the grate (see Figure 2),

$$q = q_1 + q_2$$

$$= q_1 + \frac{1}{4}(L' - L)\, y_0 \sqrt{g\, y'}$$

where y' is computed from Manning's formula, q_1 is computed from Eq. 2

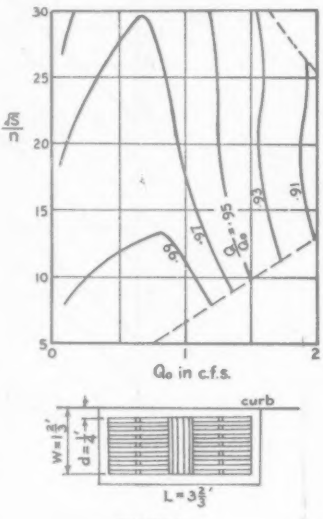


FIGURE 7.

(not from Figure 6), and L' is computed from Eq. 3a.

Example: In Figure 7 is shown a cast-iron grate used in the City of Baltimore. It is required to find the discharge into the inlet when the gutter has a straight cross-slope and $\tan\theta_0 = 18$. Here $L = 3.66$ ft., $w = 1.66$ ft., and $d = 0.25$ ft. Since there were several transverse bars in the grate, use $m = 8$ in Eq. 1.

Analysis is limited to cases where $L \geq L_0 = m\, v_0 \sqrt{\frac{y_0}{g}}$ (see Eq. 1). When

$L < L_0$, the grate becomes very inefficient. Using the values of y_0 and v_0 from Eqs. 5 and 6, and $L = 3.66$ ft., the expression above becomes

$$Q_0^{7/16}\left(\frac{\sqrt{s}}{n}\right)^{9/16} \gtrless 7.2,$$

or $\frac{Q_0\sqrt{s}}{n} \gtrless 51$ (approximately). This limit is shown by the upper dotted line in Figure 7.

If it is desired to limit the width of gutter flow to 4 ft., it is required that $\frac{Q_0}{\sqrt{s}/n} < 0.153$ (see Figure 4). This limit is shown by the lower dotted line in Figure 7.

For the given grate with $\tan\theta_0 = 18$, $\frac{w}{\tan\theta_0} = 0.0923$ and $\frac{d^2}{L^2} = 0.001166$. For the case when $\frac{\sqrt{s}}{n} = 15$, Table II shows the computation for Q. Similarly, values of Q for other values of $\sqrt{s}/n$ can be computed. The results are plotted in Figure 7.

Twenty tests were conducted on a 1:2 scale model of this grate. The difference between the computed and the observed values of capacity was usually less than 2 per cent.

Grates with Longitudinal Bars Used in an Alley

When a grate with longitudinal bars is put in an alley, the depth of flow at the center line and the mean velocity are practically the same as when half of the discharge is flowing down a gutter similar in shape to half the alley. The analysis of the capacity of the inlet can be performed, therefore, by considering that half of the flow enters a gutter inlet of half the width of the actual inlet.

Grates with Longitudinal Bars Combined with Curb-Opening

The capacity of a grate inlet with longitudinal bars combined with a

TABLE II.—Computation for Q in Illustrative Example of Performance of Grate with Longitudinal Bars [1]

		For L'				For q_2		For q_1				
Q_0 (c.f.s.)	$\frac{Q_0}{\sqrt{s}/n}$	$y_0 - \frac{w}{\tan\theta_0}$	$\sqrt{\text{Col. 4}}$	M	Q_2[2]	L'	$L'-L$	(Col. 4)[3]	q_2	$\frac{Q_0}{\tan\theta_0}$	$\frac{Lq_2}{d^2}$	q_1	q_1+q_2	Q (c.f.s.)	$\frac{Q}{Q_0}$
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
0.5	0.033	0.127	0.035	0.187	15.6	0.84	2.46	—	—	—	0.028	6.0	0.007	0.007	0.493	0.986
1.0	0.067	0.165	0.073	0.270	15.6	1.00	4.21	0.55	0.020	0.015	0.056	9.5	0.011	0.026	0.974	0.974
1.5	0.100	0.193	0.101	0.318	15.6	1.11	5.49	1.83	0.032	0.083	0.084	12.5	0.014	0.097	1.403	0.935
2.0	0.133	0.215	0.123	0.351	15.6	1.19	6.50	2.84	0.043	0.174	0.111	15.0	0.017	0.191	1.809	0.905
2.3	0.153	0.226	0.134	0.366	15.6	1.23	7.02	3.36	0.049	0.233	0.128	17.0	0.020	0.253	2.047	0.891

[1] Values in Col. 3 from Figure 4, in Col. 6 from Figure 5, in Col. 8 from Eq. 9, in Col. 11 from Eq. 4, and in Col. 13 from Figure 6.

curb-opening by its side (see Figure 3) is similar to that of the grate alone, except that q_1 is 2/3 of that of the grate without curb-opening (compare Eqs. 2 and 2a). The required length, L_0, may be taken as 4/5 of that for the case when the grate is used alone (compare Eqs. 1 and 1a).

Thus, there is little advantage in using a curb-opening beside a grate inlet without local depression. However, the curb-opening will accept the flow if the grate clogs. If the opening is placed a short distance upstream from the grate, they will act independently as two separate inlets, thus giving a much larger combined capacity. Further study is necessary to determine the best position of the curb-opening.

Summary

In this report, formulas are presented which can be used to calculate the capacity of various types of gutter inlets when there is no street depression at the inlet. These formulas have been obtained from tests on model inlets. Field tests were conducted to substantiate the reliability of the model. A study of the curb-opening inlets and gutter inlets with gutter depressions is now in progress. Results and analyses of data will be reported in subsequent parts of this series of articles.

Acknowledgments

Thanks are due to the sponsors of this research project and the Institute of Cooperative Research of The Johns Hopkins University for permission to publish this paper. The experiments were performed in the Hydraulic Laboratory of the Civil Engineering Department of the University, with the assistance of Ralph von Hohenleiten, and under the direction of the Sanitary Engineering Department.

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NRC REPORTS ON LOW-TEMPERATURE SANITARY PROBLEMS

The report on "Sewage Treatment in Low-Temperature Areas," appearing elsewhere in this issue (page 1), is one of a series on sanitary engineering problems in the North, issued by the Subcommittee on Waste Disposal of the Committee on Sanitary Engineering and Environment, Division of Medical Sciences, National Research Council. Other reports, information regarding which may be obtained from the National Research Council, 2101 Constitution Avenue, Washington, D. C., are as follows:

1. Sanitary Features of Utilidor Construction and Substitutes Therefor in Arctic Installations.
2. Sewage Pumping Stations for Low-Temperature Conditions (see THIS JOURNAL, 22, 8, 1003; Aug., 1950).
3. Disposal of Garbage in Permafrost Areas.
4. Methods and Equipment for Pit-Latrine Construction in Frozen Ground.
5. Human Waste Disposal by Small Groups and Individuals in the Arctic.
6. Insulating Materials for Sewerage Systems in Permafrost Areas.

DISINFECTION OF SEWAGE WITH CHLORINE*

II. METHOD AND UNIFORMITY OF DISTRIBUTION OF CHLORINE IN SEWAGE PLANTS

By H. Heukelekian and Robert V. Day

Of the factors that influence the efficiency of chlorination as judged by the residual coliform organisms in the effluent, contact time and dosage of chlorine and residual chlorine have been studied extensively. The third important variable, namely, the uniformity of distribution of chlorine with the sewage, has not been so extensively studied. Some laboratory experiments have been performed on the effect of agitation of sewage on the efficiency of bacterial kills. In 1936, Rudolfs and Gehm (1) reported on the effect of the rate of stirring on the percentage reduction of coliform organisms. It was found that with subresidual doses of chlorine the variations in the rate of stirring from 11 to 210 r.p.m. had little effect on the percentage reduction of coliform organisms as compared with the controls, which were mixed rapidly on the addition of chlorine and allowed to stand without further mixing during the remainder of a 1-min. contact time. From these and similar results, it was concluded that a single rapid mixing is all that is necessary to obtain maximum removal of coliform organisms up to 10-min. contact time. Stirring during longer contact periods does not lead to a greater kill of coliform organisms than does the initial mixing alone. Thus, if the chlorine is distributed uniformily through the sewage by initial mixing, no further improvement might be expected by additional stirring. Later, Eliassen, Heller, and Krieger (2) arrived at similar conclusions. They showed that when chlorine was not mixed with the sewage, but allowed merely to flow from a pipette, higher coliform densities were obtained than with either slow or rapid mixing.

The question arises of translating these laboratory results to plant conditions—for example, what constitutes adequate mixing at a plant? At many plants, chlorine is added to sewage at the entrance of the contact chamber with or without special provision for mixing the chlorine solution with sewage. Reliance cannot be placed on mixing to be obtained in the contact tanks if the initial mixing has not been adequate, because velocities in these tanks are generally so low that the degree of turbulence is insufficient to induce mixing. Adequate turbulence is, however, available in Venturi flumes or in pipelines and channels where higher velocities are maintained.

For these reasons, a study was made to determine the degree of distribution of chlorine in contact tanks of existing plants provided with various types of mixing devices.

Mixing Devices and Contact Tanks in Plants Studied

Plant A

Plant A has a total contact period of approximately 60 min. with the sewage flows encountered. The tank is provided with around-the-end type baffles and is 10 ft. deep, 11 ft. wide, and 28.5 ft. long, divided into 11 channels. The effluent from the sedimentation tank passes through a channel to a mixing

* Paper of the Journal Series, New Jersey Agricultural Experiment Station, Rutgers University, New Brunswick, N. J.

compartment, which is 18 in. square and 10 ft. deep. A baffle separating this compartment from the beginning of the first channel extends from the water surface to within 3 ft. of the bottom, thus forcing the sewage, which enters at the top, to pass downward and out at the bottom into the first channel. The chlorine hose is placed 2 ft. below the water level so as to take advantage of the turbulence.

Plant B

The contact time at plant B is approximately 45 min. with the flows encountered. The tank, 9.5 ft. deep, 12.5 ft. wide, and 28 ft. long, is divided into 11 channels with around-the-end type baffles. The effluent of the sedimentation tank goes through a channel to the mixing compartment, which is 18 in. square and 9.5 ft. deep. A baffle extending approximately 6 in. below the water level separates it from the beginning of the first channel. The chlorine hose extends to the bottom of the mixing compartment.

Plant C

Plant C has a contact period of approximately 15 min. The contact tank, divided into 7 channels with around-the-end type baffles, is 8 ft. deep, 12 ft. wide, and 18 ft. long. The effluent from the final clarifier (following a trickling filter) passes under a baffle extending to within 1.5 ft. of the bottom of the contact tank into the first channel through the entire length of the first channel. The chlorine hose is placed at the far end of the first channel and is submerged approximately 4 ft.

Plant D

The contact period provided at plant D is approximately 45 min. The tank is equipped with around-the-end type baffles, which divide the tank into 7 channels. The tank is 8 ft. deep, 10 ft. wide, and 16 ft. long. The effluent from the final clarifier passes under a baffle extending to within 2 ft. of the bottom of the tank into the first channel. The effluent thus enters throughout the entire length of the first channel. The chlorine hose is placed at the bottom of the tank at the beginning of the first channel.

Plant E

The detention period in the contact tank at plant E is 30 min. It is provided with around-the-end type baffles, dividing it into 5 channels. The tank is 4 ft. deep, 7.5 ft. wide, and 72 ft. long. The flow from the two clarifiers is collected in channels, which meet at the entrance of the first channel of the contact tank in a mixing compartment 3 ft. square and 4 ft. deep, into the bottom of which the chlorine hose is placed. The effluent passes under a baffle about 1 ft. from the bottom and then over a weir into the first channel of the contact tank.

The contact tanks described have detention periods varying from 15 to 60 min.; all of them have around-the-end baffles; one is 4 ft. deep, the rest are between 8 ft. and 10 ft. deep. As far as mixing facilities are concerned, they may be divided into three groups:

1. Plants A and B, where chlorine is added to a vertical channel with high turbulence before entering the first channel of the contact tank.
2. Plants C and D, where the sewage enters the first channel of the contact tank throughout the length of the channel and the chlorine is added at the first channel. In these cases, turbulence is at a minimum and the chances of adequate mixing are less.
3. Plant E, where the chlorine is added to a shallow mixing tank with high turbulence and then enters the first channel of the contact tank.

Experimental Procedure

The procedure consisted of taking depth samples at calculated contact times throughout the contact tanks and

determining the chlorine residual at the different depths. The depth samples were taken at 2-ft. intervals. The contact times were computed so as to theoretically follow the same portion of sewage through the contact tank. Because it is more sensitive than the orthotolidine method, the amperometric titration method was used to determine the residual chlorine.

Results

Two vertical and horizontal chlorine residual distribution studies were made at Plant A: one with the method of mixing the chlorine with the sewage, as described in the previous section, according to the plant design and operation; the second, by deliberately removing the chlorine hose from the mixing compartment and placing it 5 ft.

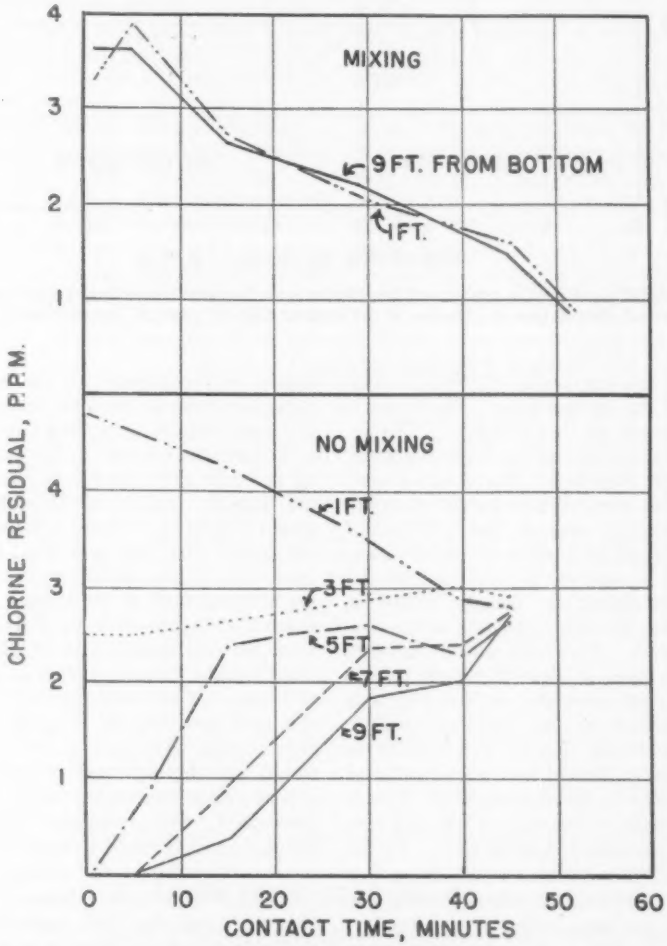

FIGURE 1.—Effect of mixing on the vertical distribution of chlorine in the contact tank in plant A (amperometric residuals).

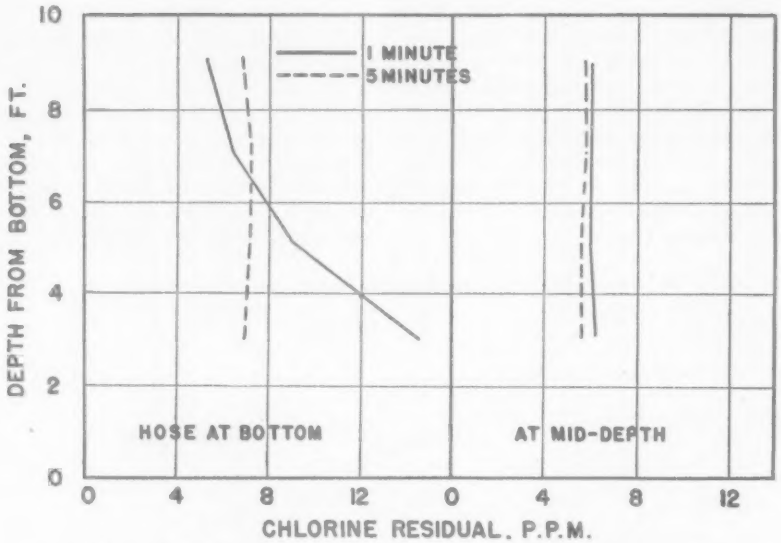

FIGURE 2.—Effect of position of the chlorine hose in a vertical mixing compartment on the vertical distribution of chlorine in the contact tank in plant B (amperometric residuals).

below the surface at the third channel of the contact tank. The latter is designated as "no mixing." The results obtained are presented graphically in Figure 1. There was a very uniform vertical distribution of residual chlorine, even at the inlet end of the contact tank, when the chlorine was added according to the design and normal operation; namely, added to the vertical channel leading to the contact tank. The residuals at different depths were so close that only the results from near the surface and near the bottom of the tank are plotted. The residuals decreased gradually as the sewage flowed horizontally around the baffles in the contact tank. This is the result of reaction of the chlorine with increasing contact time. At the end of 51 min. of contact, there was still considerable residual, which was nearly the same from top to bottom of the tank. When the chlorine hose was placed in the channel of the contact tank, there was no residual chlorine up to 1 min. contact time from the top to 3 ft. from the bottom of the tank and up to 5 min. from the top to 5 ft. from the bottom. Most of the chlorine added was in the bottom 3-ft. level of the tank. The hose was placed 5 ft. from the surface, pointing down, and the chlorine sank to the bottom in the absence of turbulent flow. Fairly uniform vertical distribution of chlorine was obtained only after 40 min. of contact time. If the total contact time in this tank was only 20 min., it can be seen readily that part of the sewage would have been over-chlorinated and a part under-chlorinated before being discharged, with resultant lower efficiency of chlorination caused by the improper mixing of the chlorine with sewage. With the same dosage of chlorine and with the same contact time, but with proper mixing, a more uni-

form and an efficient sterilization might be expected.

A different sort of experiment was tried in Plant B. The chlorine hose in the vertical mixing chamber was moved from its normal operating position at the bottom of the channel up to mid-depth. The results up to 5-min. contact time are presented graphically in Figure 2, which shows that with the hose at the bottom of the vertical mixing chamber the distribution of chlorine in the contact tank after 1 min. was not uniform vertically, but after 5-min. contact the chlorine had been uniformly mixed. With the hose at mid-depth in the mixing chamber, a uniform distribution was obtained even after 1-min. contact time. It happens that in this instance more than sufficient chlorine was used to give high residuals and with the hose at the bottom, the sewage at the top of the contact tank had more than sufficient residual. But if less chlorine had been applied, the sewage at the top of the contact tank near the inlet might have been deficient in residual chlorine. This might have given rise to inefficient sterilization, especially if in addition the contact time were limited.

Figure 3 illustrates the effect of addition of chlorine at the bottom of the first channel of the chlorine contact tank according to the design and operation of Plant D, where there is no special mixing chamber. A very non-uniform vertical distribution was obtained at the inlet end of the tank with this method of adding the chlorine. Most of the chlorine was at the bottom. It is irrelevant that there was a residual, even at the top, which was the result of a liberal use of chlorine. When chlorine is applied in more careful doses, this method of adding the chlorine may leave the top part of the tank devoid of chlorine for some distance of

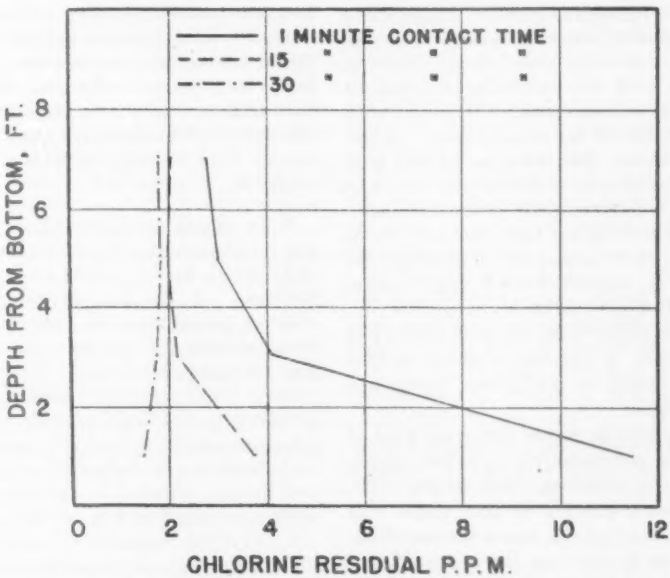

FIGURE 3.—Vertical distribution of chlorine in the contact tank in plant D with the chlorine hose at the bottom of the first channel.

horizontal flow. It actually took 30 min. of flow in the contact tank to obtain a uniform distribution of chlorine.

Similar results were obtained at Plant C, which has a similar method of addition of chlorine into the first channel of the contact tank.

An excellent distribution of chlorine is obtained in Plant E, in which chlorine is added in a shallow (4 ft. deep) mixing compartment providing a great turbulence. The results are given in Table I.

TABLE I.—Distribution of Chlorine in Plant E, as Amperometric Residuals (p.p.m.)

Depth from Bottom (ft.)	Contact Time (min.)				
	1	5	10	15	30
3	2.45	1.85	1.30	1.10	0.65
1	2.40	1.75	1.35	1.05	0.70

Discussion

Two important items of design enter into consideration of proper distribution of chlorine with sewage: one has to do with the provision of a special mixing compartment; the other, with the design of the contact tank. It has been shown that when no special mixing chamber is provided and the chlorine is added directly to the first channel of the contact tank, generally inefficient distribution is obtained by the flow of around-the-end type baffles. Distribution might be somewhat improved under these circumstances when the baffle in the first channel reaches more nearly to the bottom, creating a turbulence.

In plants provided with some kind of mixing compartment, excellent distribution is obtained. The mixing compartments studied in this paper fall into two categories, one a vertical channel with the chlorine hose placed 2 to 3 ft. below the water level. It has been shown that when the chlorine hose in such a channel reaches nearly to the bottom and the baffle in the first compartment of the contact tank is at some distance from the bottom, an improvement can be obtained by lifting the hose up to mid-depth in the vertical channel. An excellent distribution is also obtained in a shallow mixing box where the flow of two channels flowing in opposite directions meet to create sufficient turbulence. From the results presented, it appears that a simple hydraulic turbulence, either in vertical or horizontal mixing chambers, is sufficient to give good mixing and that special mechanical mixing devices are not warranted.

Summary and Conclusions

The chlorine distribution with the existing facilities of mixing chambers and contact tanks of five New Jersey plants was studied. In some instances the point of introduction of chlorine was purposely changed to show the effect on the distribution of chlorine. Samples were taken vertically along the different sections of the contact tank with proper allowance for the time of flow, and the residual chlorine was determined amperometrically. The results lead to the following conclusions:

1. In plants not provided with special mixing compartments, the chlorine distribution in the contact tanks is not uniform. A greater portion of the chlorine passes near the bottom of the tank, whereas the sewage near the top may be under-chlorinated. The turbulence in the channel of the contact tank is normally not high enough to give adequate mixing. In such tanks the turbulence can be increased and better distribution effected by lowering the baffle to within 2 to 3 ft. of the bottom.

2. Vertical channels or relatively shallow mixing compartments ahead of the contact tank with high turbulence provide adequate mixing.

3. Such hydraulic mixing obviates

the necessity of mechanical mixing for good chlorine distribution.

Acknowledgment

The work reported in this paper was supported by a fellowship grant from the Wallace and Tiernan Company, Newark, N. J.

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FIRST SEMINAR FOR EUROPEAN SANITARY ENGINEERS

The first seminar of European sanitary engineers sponsored by the World Health Organization in cooperation with the International Health Division of the Rockefeller Foundation and the Government of The Netherlands was held in The Hague from November 27 to December 2, 1950. About 40 specialists from 16 European countries met with representatives of the sponsoring agencies in informal round-table discussions on the current status of research in sanitary engineering problems and their relation to general public health.

The seminar was characterized by a keen consciousness of all participants of the interchange of knowledge between the European countries, of the necessity for collaboration between sanitary engineers and medical hygienists, and of the important role that can be played in these fields by the Environmental Sanitation Section of WHO.

Among the most important of the conclusions adopted by the seminar were the following:

1. The lack of basic information in many of the fields covered during the seminar, as well as the varying needs in different countries, indicates that fundamental research and practical investigations are urgently needed to provide practical and economic solutions to many sanitary problems. To avoid duplication and increase the productivity of individual research projects, it is advisable that a central agency be designated to coordinate and correlate this work, with particular emphasis on methods, standards, and measures, in the hope of facilitating formulation of international standards in the field. One type of problem suggested for study is that of total management of the water economy.

2. Post-graduate training of governmental sanitary staffs should be encouraged, with provision therefor on either a national or a regional basis.

3. There is a need for unhampered distribution of technical literature in the public health field and the several agencies concerned should be encouraged to facilitate this work.

RECENT DEVELOPMENTS IN DUAL DISPOSAL*

By Morris M. Cohn

Editor, Wastes Engineering; and Public Health Engineer, Schenectady, N. Y.

It is impossible to conform to the title of this paper, in the usual sense of the word "recent." Everything which has happened in the field of dual disposal is recent—so recent that the writer was present at the "gleam-in-the-eye" stage; sat in at the conception; acted as midwife at the birth of the idea; walked the floor with the astounding plan; watched it go through its share of "measles" and "mumps," with "quarantine signs" set up at the borders of many communities and, even worse, at the barricaded minds of men; helped it get into its first long pants; and, some 20 years thereafter, is reaping pride over its lusty, serviceable, early maturity.

It is difficult to write history from the close-up of the present. There is an astigmatism, a nearsightedness, which does not blend details into the whole, undistorted picture as is possible after time has taken the sharpness from the edge of individual events and blended them into a complete, historical scene. That is why autobiography is narrower than biography.

Nevertheless, after 20 years of the evolution of an idea, the revolution of a principle, and the establishment of a practice in sewage and waste disposal, it is desirable to put in the record the clear picture of the recent past and a prediction of the immediate future. That is what the writer proposes to do, briefly, although incompletely.

* Presented at 23rd Annual Meeting, Federation of Sewage and Industrial Wastes Associations; Washington, D. C.; October 9–12, 1950.

Origin and Meaning

It is always well to define the text of a discourse. What is "dual disposal?" The item is not in the dictionary of the sewage and water professions—the "Glossary of Water and Sewage Control Engineering" (1) issued jointly by the Federation and other related technical societies. Whence does it stem? What does it mean?

In October and November, 1934, the writer "coined" the expression, in an article titled "Dual Disposal of Sewage and Food Wastes" (2), to mean the mixing of sewage and properly shredded fresh food wastes, its discharge into the house sewer, its transportation through sanitary sewers, and its disposal in treatment plants as a combined liquid waste. That term caught on with a profession which likes to make "dual" use of one facility—to make two engineering blades grow where but one grew before.

When the term was coined, it referred to what was then a mere infant of an idea—the shredding of food wastes in the home, at the kitchen sink, into a water-carried waste, which was flushed into the sewer by an electrical-mechanical home appliance, the first of which was going through its "diaper days" in the writer's home.

What lies behind the first article expounding the possibilities of home disposal of food wastes is history, even though it is "recent" history. A few years earlier, two research men with inquiring minds, spurred on by a president of a great electrical firm who saw no reason why electricity could not

replace the garbage can, just as the vacuum sweeper had replaced the broom and the electric iron the sad iron, visited the writer to see what sewage looked like and to ask: "Could garbage be put down the sewer?"

The writer claims no credit for the idea. His only contribution was a mind that believes the world is not yet completed. Parenthetically, it can be said, without any hazard of sacrilege, that the world would not have been fully created if the Lord had looked upon the water and said "Why make dry land? It has never been made before."

The answer to the research scientists' question was, "Why not?" And so the stipulation was made that garbage could go down the sewer if it were converted into sewage by maceration.

Early Studies

But history began before 1930. In 1923, Fox and Davis, at Lebanon, Pa., had ground garbage in amounts and introduced it into sewers leading to the city's sewage plant. Keefer and Kratz had found by laboratory and field studies that garbage could be ground, carried by city sewers, and handled in the Baltimore sewage plant. In Durham, N. C., garbage had been ground and discharged to the sewer system during the peak waste periods associated with the watermelon season. At Indianapolis, Ind., a garbage grinding station was being set up, and when the wastes were ground, they were so completely incorporated in the sewage flow that those watching the sewage composition were not able to detect when garbage grinding was going on and when it was not.

Could garbage be discharged to the sewer? Garbage *was* being discharged to sewers. It took some messy manipulations to fish evidences of 70 kinds of food wastes from Schenectady sewage, but there they were, as reported in 1934, from bits of macaroni to a frankfurter, with enough varieties of greens to make a tossed salad.

The researchers were encouraged and development, already started, was centered on an effort to make a simple, workable, plumbing device which would meet the specification: "Grind It." Some of the early models were reminiscent of the creaking, cumbersome devices used in the torture chambers of yesteryear, but in 1933 a unit that seemed to fit the bill was ready for test.

It is no state secret that prior to this date the writer had been grinding food scraps in his basement with a hand meat grinder by cranking a handle in medieval fashion, and discharging the wastes down the toilet drain.

The 1933 device looked so good that excess enthusiasm was in order and, as a safety balance wheel, the unit was tested by 20 sanitary engineers in homes and laboratories. When approval was given by this group, as to the effectiveness of the device and the feasibility of the dual disposal process involved, actual manufacture and commercial sales efforts were started.

In a report to the manufacturer, which now sounds in the re-reading like a piece of crystal-ball accuracy, the writer predicted all of the "floor-walking" which would be needed with the infant idea before it became acceptable to municipal and engineering officials, who would be shocked by the idea of "confusing" nice clean sewage with bad-bad garbage.

Early Objections

It is hardly necessary to review how the prophesies of doom piled in, but for the need of completeness in historical presentation the following list is presented:

1. No safe, clean grinder could be developed for the use of careless home users.

2. Home plumbing would plug up with wastes.

3. Plumbing traps would be "blown."
4. The water reservoirs would run dry from the hundreds of gallons of water needed for each grinder.
5. House sewers would clog with the "stuff."
6. Street sewers would fill up with food wastes.
7. Sewage treatment processes would fail.
8. Plant capacities would be overtaxed.
9. Foul odors would be produced.
10. Streams would be destroyed.
11. Garbage-fed pigs would starve to death.
12. Sewage plant operators would work and worry themselves to death.
13. Sewage plant additions would bankrupt municipalities.
14. The "perfect crime" would be possible by disposing of the *corpus delecti* down the drain.
15. Everything else, save juvenile delinquency, would result.
16. Anyway, it had never been done before, and the idea was ridiculous in the first place.

So went the story of the predictors of failure—and they persist in a limited number of municipalities and in some other quarters. However, there were also others who lent encouragement and vocal and written support to the new idea.

Objections Unfounded

Nevertheless, history must record that these dire results have not materialized. In the pioneering article, referred to above, and a companion article (3), the writer predicted these dual disposal factors:

1. Sewage solids and food wastes are basically the same, and they act the same. Much food wastes are already in sewage as a natural component of "sewage"; size is the limiting factor, as scraps which go down the drain are sewage and those which are scraped out of the sink are garbage. No regulations as to strainer size are in use.
2. A suitable, safe, clean, electrically-operated grinder could be provided for home use.
3. Home wastes could be shredded to suitable size (not so small that it would be colloidal, or so big that it would be "unmiscible" with sewage) and mixed with sewage into a liquid waste, which is sewage, all without maiming, killing, or murdering the populace.
4. The water required for operating the grinder would be less than 2 g.p.d. per capita, or between 1 and 2 per cent of the total per capita sewage flow.
5. The best operation of a grinder would come with the use of controlled water, since grinding with cold water is an aid to the coagulation and homogenization of greases; the use of controlled quantities of water is essential to effective grinding and flushing of wastes into the sewer system.
6. Home plumbing lines and appurtenances would function successfully.
7. Public sewers would handle food wastes as readily as heterogeneous sewage solids.
8. No sewer odors would result.
9. Food wastes would settle readily in settling tanks.
10. These food wastes solids would digest readily.
11. The sludge produced could be filtered, incinerated, made into fertilizer, or otherwise disposed of.
12. Settled effluent would be oxidizable, chlorinateable, and disposable.
13. Sewage plants would not be immediately overtaxed and they would not have to be immediately rebuilt or enlarged. The use of home units would grow slowly enough for municipal officials and engineers to learn the design factors for adequate treatment of dual wastes.
14. Cities would not be bankrupted. In fact, dual disposal might even become an economical two-blades-for-one process in the future.

15. The day would come when plants would be designed and built to meet their dual duty, with capacities increased for solids handling and secondary treatment of effluents. However, the need would be one of capacity, not change in basic processes.

16. Operators would not perish from mortification and scientific failure. In fact, they might even benefit from their ability to perform a double public service, and from the public's interest in improving facilities which will give them freedom from the age-old chore of toting garbage to an odor-laden, fly-ridden, rodent-bitten, snow-drifted, frost-hardened, wind-swept, dog-pawed, man-battered container.

17. Finally, even though it had never been done before, it might be a creditable idea in the first place to remember that the sanitary engineer's function is sanitation and that public service supersedes everything.

There is not much more for history to record. Twenty-five years ago, the idea of shredding food wastes in the home and converting them into a normal component of sewage would have been inconceivable; today the process has gone through the thrill of "gleam," the work of "conception," the pains of "birth," the pangs of childhood, and is now reaching a state of maturity.

Research has confirmed, in great measure, the crystal-ball predictions of nearly two decades ago, for the accuracy of which the writer claims no individual credit because they were based on beliefs, opinions, and findings of many persons who had already investigated the aspects of mass central grinding of garbage and of the discharge of the resultant materials into sewers or directly into sewage treatment plant units.

Present Status

In the meantime, home food waste grinding and shredding units have become an adjunct of American home life in as full degree as was predicted by market research experts, who have a way of manipulating interviews, curves, and charts like an engineer handles a slide rule, to come up with plausible predictions. A dozen and more manufacturers and distributing companies are marketing that many devices, all connected to home and public sewers.

Over a half-million units are in use in the United States, in over 350 communities where authorization is given. Some communities still prohibit the use of home units, some by ordinance and others by unwritten ruling for reasons of ineffective sewer design, inadequate sewers, or overloaded or no sewage treatment facilities.

Many units are operating on septic tanks. U. S. Public Health Service tests have shown, in preliminary way, that food wastes do not affect operation of septic tanks, or the character of the effluent therefrom. The trend is toward requirement of increase in septic tank capacity by 25 to 50 per cent to provide for dual disposal.

Many communities are beginning to show an appreciable percentage of homes using food waste units. Pines Village in New Orleans, La., will be exclusively provided with home units; other communities are experiencing mass installation in new home areas, in apartment houses, etc.

Many communities have revised existing ordinances to permit discharge of food wastes into sewers. There is a trend toward specifying the character of the ground wastes and the safety and dependability of the appliance.

There is a definite trend towards distinguishing between "garbage" in the "raw", state, and ground food wastes, with the former prohibited and the latter approved for disposal to sewers. The Model Sewer Ordinance of the Federation (4) makes this distinction, as do a number of communities where antiquated local regulations included the prohibition that such

items as feathers, manure, butchers' offal, steam, excelsior, straw, garbage, etc., be kept from sewers.

There is a trend towards technical interest in the use of commercial units in communities as a natural supplement to home units, with Dearborn, Mich., recently ordaining their compulsory use in all new buildings, except 1-, 2-, and 4-family residences, and in all buildings remodeled or altered or designed, equipped, and used for storing and preparing various types of foodstuffs for human consumption.

Also, there is Jasper, the progressive community in South Indiana, which, backed up by the first state law in history that permits the purchase, installation, and financing of home waste units by municipalities as a sanitation utility, has outlawed the use of garbage cans as of August 1, 1950, and has contracted for the installation of home units for all properties which purchase them. In this town more than 80 per cent of the homes now have units. Here is one community and one state action which is the culmination of over 20 years of nurturing an idea, research, manufacturing, development, technological improvements, and technical education.

Just as the early idea could have been nipped off and the "gleam" of expectancy extinguished had it not been for an open mind, so, again, open minds which believe that because something has never been done before does not mean that it cannot be done now, have moved the dual disposal process along another long step. To the consulting firm which engineered the specifications and testing of home grinding units and designed the first municipal dual disposal plant in history; to the city officials who had the progressiveness to embark on this venture; to the people of Jasper; to the State Sanitary Engineer, the State Health Department, and the state legislators who fashioned the law which makes possible a new financing approach to dual disposal, history and the sewage works profession owe a debt of gratitude. The story of Jasper will best be told when the sewer system, the treatment plant, the diluting stream, and the environmental sanitation and health factors are brought into focus. Jasper may be the forerunner of other communities where dual disposal on a full-scale basis will be adopted.

The historical view of things has a way of bringing a true humility to those who think that progress began with their appearance on the scene. It is with this sense of humility for the very small part he had in helping a new process in home and community sanitation over the hurdles of its early and trying days, that the writer would like to close this attempt at recording a bit of sanitation history. It took the hopes and efforts and financial faith of many people to make dual disposal the reality it is today. We are only at the beginning of what may become a great, universal utilization of this development. The work of many more people and agencies will be required to carry on in the future. That is how history perpetuates itself.

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Industrial Wastes

POLAROGRAPHIC DETERMINATION OF METALS IN INDUSTRIAL WASTES

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In a preceding paper (1), colorimetric methods for the determination of certain metals in sewage and industrial wastes have been presented. As it is possible, in many cases, to analyze a mixture of several metals by polarographic means in much less time than would be required for a similar colorimetric analysis, a systematic procedure has been worked out for the polarographic determination of cadmium, chromium, copper, iron, nickel, and zinc in sewage and industrial wastes. The polarographic methods presented here are intended to supplement the colorimetric methods described previously; however, they are more restricted in their applicability due to the fact that polarographic measurements cannot be made conveniently on water samples containing less than 3 to 5 p.p.m. of the desired constituent, whereas the same determinations can be made colorimetrically at concentrations as low as 0.05 p.p.m. This suggests that polarographic methods should be most useful to analysts in manufacturing plants confronted with waste disposal problems, as their samples are taken near the source and are still relatively concentrated. It is assumed that many laboratories engaged in this kind of work will possess polarographic equipment.

Because it was recognized that polarographic methods will generally be somewhat inferior to corresponding colorimetric procedures with respect to sensitivity, accuracy, and freedom from interference, emphasis has been placed on devising methods which are rapid and permit the simultaneous measurement of several constituents in a single polarogram. It is well established that when two or more electroreducible ions are present in a solution, all the ions may be determined from a single polarogram provided their half-wave potentials are adequately separated; generally speaking, the separation should be at least 0.2 volts, otherwise the waves coincide to such an extent that it is impossible to ascertain the inflection point dividing them. By proper choice of the supporting electrolyte and the oxidation state of the metals present, it is often possible to space the waves so that three or four cations can be determined simultaneously. In addition, use of supporting electrolytes in which interfering ions are insoluble also is helpful in increasing the specificity of the measurement, provided the precipitates formed do not absorb or occlude the desired constituent. In the systematic procedure given herein, polarograms of three solutions prepared in different supporting electrolytes from aliquots of the original sample are sufficient to determine cadmium, chromium, copper, iron, nickel, and zinc in the presence of each other.

Technique of Polarographic Measurements

The fundamental principles of polarography are adequately reviewed

elsewhere (2); however, the following points are discussed briefly because they are important in determining the accuracy of the results obtainable with the polarograph.

Removal of Oxygen

Dissolved oxygen is reducible at the dropping mercury electrode and must be removed in order to avoid interference with the waves of the constituents being determined. This can be effected by bubbling a stream of nitrogen or hydrogen through the sample for 10 min. prior to electrolysis. Nitrogen from commercial cylinders usually contains some oxygen, and should be purified by passing through a trap containing a suitable absorbent.

Residual Current

All polarographic measurements, both for calibration and analysis, must be corrected for residual current. The proper correction should be determined by obtaining a polarogram of the supporting electrolyte alone over the potential range employed in the actual analysis.

Temperature Effects

Diffusion currents increase appreciably with increasing temperature, the effect amounting to 1.5 to 2.0 per cent per degree for most ions. For highest accuracy the polarographic cell should be placed in a thermostat, or a calibration should be run at the same temperature prevailing during the analysis.

Calibration

The relationship between diffusion current and concentration is linear for all systems utilized in this work. Calibration of the polarograph is readily carried out by measuring the diffusion current corresponding to a known concentration of the desired constituent and calculating from the data obtained the value of k in the expression:

$$\text{Diffusion current} = k \times \text{concentration}$$

The calibration constant will be valid only as long as the temperature, mercury pressure on the capillary, and dimensions of the capillary remain unchanged.

Measurement of Diffusion Current

When only a single wave, or a pair of waves separated by a horizontal plateau is to be measured, it is satisfactory to determine the currents at potentials corresponding to the bottom and top of the waves, the diffusion currents being computed by difference after subtracting the increase due to the residual current. However, if the waves are not widely spaced, as in the case of the simultaneous determination of cadmium, nickel, and zinc, the current should be measured at 0.03-volt intervals over the entire region of interest and the data graphed to ascertain the current at the actual inflection points. It should be noted that the accuracy of measuring a small wave preceded by a much larger one is inevitably lower than usual and may be entirely unsatisfactory if the difference in concentration is too great.

Determination of Copper and Iron

Copper and iron may be determined simultaneously in 0.5 M perchloric acid solution without interference from other metals, although chromium must be reduced if originally present in the sexivalent state. The wave due to iron begins immediately at 0 applied e.m.f., and the copper wave follows at + 0.02 volts versus the saturated calomel electrode. Contrary to a statement in the literature (3), it was found that a mercury pool anode can be used for determining ferric iron in acid supporting electrolytes.

Determination of Chromium

Chromium is usually determined polarographically as chromate in a sodium hydroxide supporting electrolyte, a 1 M sodium hydroxide solution being recommended for the purpose

(4). Only lead gives an interfering wave; if present, lead must therefore be removed from the original sample by precipitating as the sulfate. Copper shows weak amphoteric properties and is sufficiently soluble in 1 M sodium hydroxide to give a distinct wave preceding the chromate reduction; as the half-wave potentials are -0.42 volts and -0.85 volts, respectively, for copper and chromate, no interference problem is involved.

Determination of Cadmium, Nickel, and Zinc

An ammoniacal tartrate supporting electrolyte was selected for the determination of cadmium, nickel, and zinc, in preference to the usual ammonia-ammonium chloride buffer, in order to avoid losses resulting from adsorption on the hydrous oxide precipitates of metals insoluble in ammonium hydroxide. However, an investigation of interferences showed that iron and tervalent chromium must be absent. Ferric ion shows an ill-defined wave starting around -1.0 volts. Chromic ion does not give a polarographic wave in ammoniacal tartrate, but has the peculiar effect of markedly suppressing the diffusion current of other ions. Separations of iron with "cupferron" and chromium by precipitation as barium chromate are utilized to circumvent this interference.

Procedure for the Polarographic Analysis of Industrial Wastes

1. Apparatus

1.1. Polarograph. Any of the commercially available instruments, manual or recording, may be employed.

1.2. Nitrogen tank and purification train. Nitrogen gas from a cylinder is purified by bubbling through a gas-washing bottle equipped with a fritted glass orifice containing Fieser's solution (see 2.12 below), and then through a second washing bottle half filled with 0.01 M sodium hydroxide. When deoxygenating ammoniacal solutions, the 0.01 M sodium hydroxide is replaced with 1.0 M ammonium hydroxide.

1.3. Separatory funnels, 125-ml. Squibb form, with ground glass stoppers.

2. Reagents

2.1. Perchloric acid, 60 per cent.

2.2. Perchloric acid, 3 M. Dilute 1 volume of 60 per cent acid with 2 volumes of water.

2.3. Hydrogen peroxide, 3 per cent.

2.4. Sodium sulfate, 10 per cent. Dissolve 10 g. of cp. Na_2SO_4 in 90 ml. of water.

2.5. Sodium acetate, 20 per cent. Dissolve 20 g. of cp. $NaC_2H_3O_2 \cdot 3H_2O$ in 80 ml. of water.

2.6. Cupferron reagent, 1 per cent. Dissolve 1 g. of the analytical reagent in 100 ml. of water. This solution should be kept in a cool place and prepared fresh every three or four days.

2.7. Chloroform, reagent grade.

2.8 Barium chloride, 1 M. Dissolve 25 g. of $BaCl_2 \cdot 2H_2O$ in water and dilute to 100 ml.

2.9. Ammonia, 5 M—sodium potassium tartrate, 1 M, solution. Dissolve 282 g. of $NaKC_4H_4O_6 \cdot 4H_2O$ in water, add 333 ml. of concd. NH_4OH, and dilute to 1 liter.

2.10. Sodium hydroxide, 2 M. Dissolve 80 g. of NaOH in water and dilute to 1 liter.

2.11. Gelatin, 0.5 per cent. Dissolve 0.5 g. of gelatin in 100 ml. of water, heating to hasten dissolution, and add 3 or 4 drops of toluene as a preservative. Prepare a fresh solution every 3 or 4 days.

2.12. Fieser's oxygen absorbent. Dissolve 20 g. of KOH in 100 ml. of water, then add 2 g. of sodium anthraquinone-β-sulfonate and 15 g. of sodium hydrosulfite ($Na_2S_2O_4 \cdot 2H_2O$). Stir to obtain a clear, blood-red solution and cool before use.

2.13. Standard metal solutions, 1,000 p.p.m. Solutions of cadmium, copper,

iron, nickel, and zinc are prepared for calibration purposes. Dissolve 1.000-g. portions of the pure metals in 10 ml. of 1:1 nitric acid, heating to effect dissolution. Then add 50 ml. of water and boil to expel oxides of nitrogen. Cool and dilute to 1 liter in a volumetric flask.

2.14. Standard potassium dichromate solution, 1,000 p.p.m. chromium. Dissolve 2.830 g. of potassium dichromate in water and dilute to 1 liter.

3. Preliminary Treatment of Sample

Agitate the sample to obtain a homogeneous suspension of solids, then measure out a 1-l. sample by means of a volumetric flask. Acidify the sample with 5 ml. of concentrated nitric acid and evaporate to 15 to 20 ml. in a large evaporating dish. Transfer the solution, together with any solids remaining in the dish, to a 125-ml. conical flask, then add 5 ml. additional nitric acid and 5 ml. of 60 per cent perchloric acid. Evaporate slowly on a hot plate until dense white fumes of perchloric acid appear in the flask, then fume the sample for 4 to 5 min. to insure complete oxidation of chromium. Cool somewhat, add 50 ml. of water, and boil to expel chlorine. Cool and transfer the solution to a 100-ml. volumetric flask. If lead is present, add 10 ml. of 10 per cent sodium sulfate to precipitate the lead as $PbSO_4$, then dilute to the mark with water. Aliquots of this solution are taken for the determinations given below, which are satisfactory only when the concentration of the desired constituent in the original sample exceeds 5 p.p.m.

Copper and Iron

Transfer a 25.00-ml. aliquot of the sample to a 125-ml. conical flask and add 5 ml. of 3 M perchloric acid. Reduce any dichromate present by adding 3 per cent hydrogen peroxide one drop at a time until reduction is complete, as shown by the non-appearance of the blue perchromate color as the drop of peroxide enters the solution. Boil gently for 5 min. to decompose the excess of hydrogen peroxide. Cool the solution and transfer to a 50-ml. volumetric flask, add 2 drops of methyl red as a maximum suppressor, and dilute to the mark. After bubbling nitrogen through the solution for 10 to 15 min., measure the diffusion current at + 0.15 volts and − 0.30 volts versus the saturated calomel electrode and correct the readings for residual current as determined on a separate polarogram of a solution of 0.3 M perchloric acid. The reading at + 0.15 volts then represents the diffusion current of iron and the difference between this reading and the reading at − 0.30 volts is the diffusion current of copper. The measured diffusion currents are converted to concentration by comparing with the diffusion currents obtained on running a standard containing 5.00-mg. quantities of iron and copper in 50 ml. of 0.3 M perchloric acid.

In the absence of chromium, the addition of hydrogen peroxide and subsequent boiling is omitted, and the 25.00-ml. aliquot is placed directly into the 50-ml. volumetric flask.

Cadmium, Nickel, and Zinc

Place a 25.00-ml. aliquot of the sample in a 125-ml. separatory funnel and add 10 ml. of 20 per cent sodium acetate. Add 20 ml. of chloroform, then 10 ml. of 1 per cent cupferron and shake immediately to extract the precipitated cupferrates. Draw off and discard the chloroform layer. Add 20 ml. more chloroform and 5 ml. additional cupferron and extract again. Repeat this procedure, if necessary, until a nearly colorless chloroform layer is obtained. Finally, shake with two additional 10-ml. portions of chloroform to remove any excess cupferron from the aqueous phase.

Run the aqueous solution into a 100-ml. volumetric flask, rinsing the funnel with a small volume of water from a

wash bottle. If the sample contains chromium, add 5 ml. of 1 M barium chloride. Then neutralize to methyl red with ammonium hydroxide, add 20 ml. of 5 M ammonia—1 M sodium potassium tartrate solution and 2 ml. of 0.5 per cent gelatin, and dilute to the mark. Record the complete polarogram from 0 to − 1.6 volts after passing nitrogen through the solution for 10 min. Half-wave potentials are − 0.80 volts versus the saturated calomel electrode for Cd^{++}, − 109 volts for Ni^{++}, and − 1.36 volts for Zn^{++}. Measure the diffusion current for those waves which appear, making suitable correction for the residual current. The measured diffusion currents are converted to concentration by comparing with the diffusion currents obtained on running a standard containing 10.00 mg. of Cd^{++}, Ni^{++}, and Zn^{++} per 100 ml. The standard is prepared by pipetting 10.00-ml. portions of the standard metal solutions into a 100-ml. volumetric flask, adding 20 ml. of 5 M ammonia—1 M sodium potassium tartrate solution and 2 ml. of 0.5 per cent gelatin, and diluting to volume.

Chromium

Transfer a 25.00-ml. aliquot of the sample to a 125-ml. conical flask, add a drop of phenolphthalein and neutralize with 2 M sodium hydroxide. Add 50 ml. excess 2 M sodium hydroxide and heat the solution to boiling. Cool, transfer the solution to a 100-ml. volumetric flask, and dilute to volume with water. Pass nitrogen through the solution for 10 min., then measure the current at − 0.60 and − 1.10 volts versus the saturated calomel electrode. Compute the diffusion current of chromate from the difference in the measured currents and correct for residual current as determined on a blank solution of 1 M sodium hydroxide.

Convert the diffusion current reading to concentration by comparing with the diffusion current of a standard containing 10 mg. of hexavalent chromium per 100 ml. This standard is prepared by pipetting 10.00 ml. of standard potassium dichromate solution into a 100-ml. volumetric flask, adding 50 ml. of 2 M sodium hydroxide, and diluting to volume.

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EXPERIENCE WITH CHLORINATION OF CYANIDES IN THE GENERAL MOTORS CORPORATION *

I. INTRODUCTION

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Since early 1945, General Motors Corporation has been active in the promotion of better industrial waste control. As part of the program in this respect, GMC formed what was known as the Industrial Waste Treatment Committee to investigate and advise on all problems connected with application of waste control in the plants. It was soon found that emphasis should not be placed on treatment of wastes, but rather on better control. Accordingly the name of the group was changed to the Industrial Waste Control Committee.

The name of this committee describes the general objective of waste control activity in GMC—that of better control over the process for the purpose of minimizing the amount of waste matter lost, and when no possibility of chemical recovery is possible, to prescribe the proper treatment method for destruction of the material. This program has also been carried out in the case of cyanide treatment, so that the primary emphasis is placed on prevention of loss of cyanide. The methods used for reducing the quantity or concentration of these wastes may be summarized as follows:

1. Better control of the processes involved to make more efficient use of chemical agents and less wastage by spillage and carryout.

2. Recovery of chemical agents by the employment of reclaiming devices, either before or after the process.

3. Replacement of the process by a process which will produce the same results at a comparable cost, but which will not result in the formation of an obnoxious waste product.

Two examples of this latter procedure applying definitely to the disposal of cyanides are:

1. Substitution of "gas cyaniding" for the molten salt bath cyanide treatment of steel. Several plants are considering the substitution of the ammonia type furnace for the molten salt bath.

2. Substitution of an acid copper plating system for the copper cyanide bath. Recent developments in this field make this process attractive.

Other Methods under Study

In addition to the efforts of GMC along these lines, a considerable amount of attention has been given to the development of other methods of disposal of cyanides which do not employ chlorine gas. This investigation is being prompted by the high cost of the chlorine system and the disadvantages and inconveniences of this method of treatment. The methods now being considered include:

1. Use of thiosulfates for conversion of the cyanide to thiocyanates. It is recognized that the thiocyanates possess a certain amount of toxicity in themselves, but that this toxicity is an extremely small proportion of that

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exhibited by the cyanides. It is believed that by proper manipulation of the process, and subsequent dilution in the remaining effluent waters from the plant, an effluent of satisfactorily low toxicity will be obtained.

2. Use of certain metals already existing in the plant wastes as complexing agents with the cyanides. The metal complexes formed in this way are extremely tightly bound, and the free cyanide obtainable by dissociation of these complexes is too low to exert toxic effects on natural life in streams.

3. Precipitation of cyanides as heavy-metal cyanides, which may be re-used in plating processes. Some effort is being made to form precipitates of zinc, copper, and cadmium cyanide by the addition of the respective heavy metal to the waste solution. Separation of this precipitate is expected to provide a replacement chemical for use in the plating bath.

4. Some attention is being paid to the possibility of reacting the copper-ammonia complex with cyanide to form cyanates and insoluble cuprous cyanide. Some copper plating processes provide the copper-ammonia complex in the rinse water in sufficient quantity to react with the available cyanides from other wastes.

5. Substitution of sodium hypochlorite solutions for chlorine gas to eliminate difficulty from high heat of solution and low solubility in connection with chlorine gas application.

Chlorine Gas *vs.* Bleach Powders

With respect to activity in the use of chlorine for destruction of cyanides, some plants have attempted to use bleaching powder for small quantities of cyanide and liquified chlorine gas for treatment of larger quantities. In general, it has been found that bleaching powder is unsatisfactory due to the formation of large quantities of sludge and the consequent difficulty in disposal of the sludge. Chlorine gas supplied from cylinders has been found to be much more convenient and less costly from the over-all standpoint.

Some difficulty has been experienced with certain applications due to the escape of chlorine gas from the treatment system. This difficulty seems to be due entirely to inefficient absorption of the gas in the solution, and could be corrected by proper modification of the treatment equipment. In these particular installations, however, the chlorination system has achieved some measure of disrepute due to the difficulties experienced in adjoining buildings from the escape of the gas. At one plant the chlorination system was located immediately beside the heater intake ducts for the building, with the result that escaping chlorine gas was drawn into the building by the fans and distributed throughout the entire building. This resulted in an immediate shutdown of the plant and the decision to use some other means of disposal for the cyanides.

Certain divisional plants in GMC have found that their old practices in dumping cyanide skimmings have had to be revised in view of the increasing knowledge of the properties of cyanide wastes. At one division, the cyanide skimmings from heat treatment baths were dumped within the plant area and simply covered with earth. Eventually, however, a member of the plant supervisory staff realized that the water supply for the entire plant was being drawn from shallow wells within the plant boundary and that some possibility of cyanide contamination by leaching through the soil was possible. Close control over the quality of the well water in this plant gave some measure of protection, as continuous chlorination was practiced. However, the plant decided that some steps had to be taken to destroy the cyanides in the ground, and, accordingly, spread large quantities of bleaching powder over the area. The bleaching powder was raked or plowed under in the hope

that subsequent rainfall and sprinkling would cause destruction of the cyanide. No check was made as to the efficiency of this system.

In the succeeding papers it will be seen that primary emphasis has been placed on the safety of the men handling chlorination systems. In general, GMC plants use simple equipment for dissolving and chlorinating the cyanides, but go to extreme measures in supplying the area with safety devices for the protection of personnel handling these materials. The difficulties experienced by these plants in starting and maintaining operation of their chlorination systems should be of considerable interest to those charged with the responsibility of similar installations.

II. DETROIT DIESEL ENGINE DIVISION

By P. W. Uhl

Chemist, Detroit Diesel Engine Division, GMC, Detroit, Mich.

The following is a somewhat chronological plant report on operations connected with the first attempts to destroy cyanide wastes from heat treat, fused-bath skimmings. Although the report may appear somewhat discontinuous, it does give a fairly complete picture of operations and progress made, along with conclusions arrived at and rules formulated for future conduct of operations. All operations were conducted at the Detroit Diesel Engine Division, General Motors Corporation, Detroit, Mich. The process is in daily use.

Original Installation

Operations for disposal of cyanide wastes by chlorination were started on October 13, 1947, by dissolving one

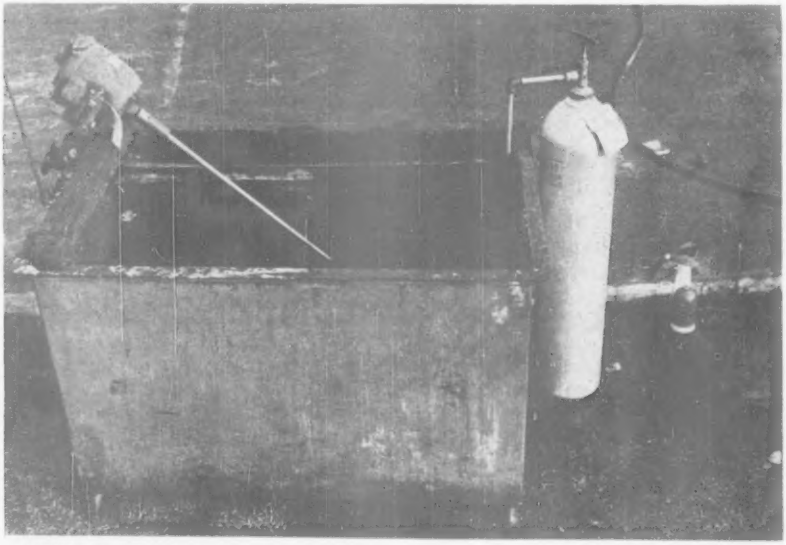

FIGURE 1.—Original setup for chlorination of cyanide wastes at Detroit Diesel Engine Division, GMC, showing mixer, chlorine apparatus, and protective equipment.

drum of cyanide pot skimmings in water in the tank shown in Figure 1. For the experimental application the chlorine cylinder was installed close to the tank. Protective equipment included only a face shield and rubber gloves. The tank capacity was about 300 gal. with the solution level maintained 1 ft. below the top of the tank.

Wastes or skimmings as received from heat treat departments were not well segregated as to types—all types of skimmings were mixed, including neutral salts (chlorides), martempering (nitrate-nitrite), and cyanide types. The first drum of skimmings to be treated was largely of a cyanide type (containing chlorides, carbonates and cyanides). The drum containing the material was placed on its side in the treatment tank, water was added, and stirring started to aid in dissolving the contained material. Representatives from the maintenance, safety, and metallurgical departments were present during the start of operations and most of the time during which operations were continued by the writer.

Proper safety equipment was worn by workmen handling materials and assisting in operations. Running water was provided for washing gloves or aprons where contact with the drum or its contents was unavoidable.

The stirring apparatus was shut off and the addition of chlorine adjusted to a point where only a small amount could be observed as escaping. The valve setting was left in this position and the stirring apparatus again started. Due to the rapid mixing, little if any chlorine could be observed as escaping from the tank while the solution was being stirred.

The tank was located 30 ft. from the wall of the incinerator building. An ash removal ramp rises from the building behind the tank, and it was considered that excess chlorine might possibly flow down this ramp to produce a high concentration at the lowest point. A check for chlorine at this point revealed no noticeable concentrations.

The pH of the solution was found to be 11 and did not change appreciably during the period of operation. The temperature at no time exceeded 100° F.

Now, as then, chlorine is added to the tank while the lightning mixer is operating. The chlorine pipe extends to the bottom of the tank to a T-fitting supplied with two sections of pipe extending across the width of the tank. These pipes have been drilled with small holes and are plugged at each end. No check valve was used in the original installation.

Water was supplied by a hose extending from the incinerator building and also high-pressure steam where hot water was needed to dissolve mixed salts. The electrical connection for the motor is carried from the incinerator building and can be disconnected at the motor.

After the addition of chlorine from the cylinder for one-half hour, a sample of the well-stirred solution was tested in the laboratory. The cyanide content was found to be 0.22 per cent (as NaCN).

The test was run on 50 ml. of the filtered sample. Two or three ml. of ammonium hydroxide were added. To the sample thus prepared, 1 ml. of 10 per cent potassium iodide solution was added and the whole titrated with standard silver nitrate solution. (One ml. is equivalent to 1 per cent of sodium cyanide when a 100-ml. sample is used.)

At this point it was decided that computation of cyanide present served no useful purpose, as it was certain that if measurable amounts existed by this method, the solution contained too much cyanide for dumping. It was decided to record only the amount of the silver nitrate required for test to indicate the progress being made.

On this basis, the following results were observed at test intervals:

Bubbling Rate (Cl)	Chlorine Added	Titration (ml. $AgNO_3$)
Slow	30 min.	22.2
Rapid	15 min.	15.0
Rapid	15 min.	10.0
Rapid	30 min.	1.0

The solution was allowed to remain idle over the week-end. A new sample was obtained from the well-stirred bath on resumption of operations on Monday morning. 5.2 ml. of silver nitrate were required. It was at first believed that this rise in the amount of titrating solution was due to incomplete solution of the salts in the tank. Such, of course, could have been the case; but later tests under similar conditions indicated a recurrence of similar conditions, especially when organic or oily matter was present in or on the solution being treated. The fact is now quite well established that this condition is caused by the cyanates being reduced to cyanide. A number of authorities indicate that such reactions may be reversible under certain conditions.

Observations so far had indicated the following course of action:

1. Chlorine should be added until an excess exists in all solutions treated.
2. Extreme caution should be exercised to insure solution of all soluble material.
3. Skimmings from each type of bath should be segregated.
4. Oily or other organic materials should be kept out of contact with skimmings.
5. A previous decision to provide suitable containers, so made as to prevent personal contact with contents and for use in collecting cyanide wastes only, should be rigidly enforced. (Several novel suggestions had been advanced for design of such containers and were receiving full consideration.)
6. Careful consideration should be given to any future ideas as to proper handling to avoid splashing or other possible personal contact with cyanide in any form.

The solution previously described was further treated for one-half hour with rapid addition of chlorine. The titration showed no presence of cyanides and the solution when diluted and heated to boiling gave off unmistakable fumes of chlorine. The solution under treatment was then allowed to stand overnight and again tested with the same results.

This tank was drained directly to the pavement after treatment, and the treated liquid flowed to a near-by sewer opening. The white material on the ground around the tank (Figure 2) is calcium hypochlorite for oxidation of any cyanide solution spilled during the operation. The undissolved solids (scale, small metallic parts and chips, etc.) were shoveled into containers with other solid wastes intended for dumping.

The next drum of material to be treated consisted largely of neutral salts with a relatively low cyanide content. Solution of this material was difficult in water so the tank and its contents was heated to hasten solution. The resulting solution was stirred overnight without the addition of chlorine (Nov. 18, 1947).

On the next morning, the drum in which the skimmings had been obtained was removed from the solution and rinsed thoroughly with water, the rinsings being added to the contents of the treatment tank. Examination of the drum—one in which cyanide salts had been purchased—indicated that it was a poor container for handling wastes of this nature, as its shape made it difficult to handle without splashing the solution. One of the men employed in assisting with the operation suggested the use of a raincoat to prevent splashed material from coming in contact with skin or clothing (Figure 2). It was felt, however, that

FIGURE 2.—Second step provided removal of chlorine cylinder to prevent splashing and addition of raincoat for protection.

the raincoat could be discarded if and when suitable containers for handling became available.

One-half hour of rapid chlorination served to destroy all traces of cyanide in the solution of the material described and free chlorine was found to be present in the sample of the treated solution, which was then discarded as before.

The third batch of material for disposal was received in two drums. In this batch was obtained what one of the men assisting called the "jackpot." The waste material consisted of skimmings from cyanide pots, neutral salt baths, martempering (nitrate-nitrite) baths, scale, metallic chips, and some small metallic parts. Solution in water was difficult. The cyanide content was quite low, requiring only 8.5 ml. of silver nitrate.

The rate of addition of chlorine was kept at a minimum because of the formation of dense clouds of nitrosyl chloride (NOCl), formed by reaction of the chlorine with the nitrates present. Large quantities of chlorine were required to appreciably reduce the cyanide content. One-half hour of chlorination reduced the titration only from 8.5 ml. to 5.2 ml. of silver nitrate. The pH of the solution dropped during this time from 11 to about 9. This was probably due to the neutralizing effects of the acidic gases formed in reaction with the alkaline portion of the bath. Additions of caustic soda were found necessary to maintain the alkalinity of the bath.

Rapid addition of chlorine to the bath released dense clouds of the reddish-brown NOCl, so the rate of addition was cut to a minimum. Fortunately, the location chosen for the disposal apparatus was remote from buildings and fumes formed were dissipated before becoming obnoxious. Operations were conducted from the windward side of the tank, thus protecting against inhalation of gases formed.

Operations to this point indicated the following salient facts, some of which have been previously mentioned:

1. Wastes must be segregated as to types. Indiscriminate mixing of wastes

results in uneconomical operation and possible formation of new compounds with indeterminate effects.

2. By far the most dangerous part of operations performed is that of manual handling of materials intended for disposal. The more nearly this can be done mechanically, the less the possibility of dangerous personal contact.

3. Accurate and complete chemical tests must be made before final disposition is permitted.

4. A hinged cover which may be rinsed into the tank is desirable while stirring the solution, to prevent droplets from being thrown out.

5. A waste container for collection of cyanide wastes must be of such form as to allow it to be inverted and dumped into the treating tank before the addition of water.

6. The cylinder containing the chlorine to be added should be remote enough from the treating tank to obviate the possibility of splashing solution on it. If not properly rinsed off, the chlorine container may cause contact between materials splashed on it and persons handling the empty container.

7. The fact that extremely poisonous materials are being treated with an extremely poisonous gas should be emphasized sufficiently to prevent anyone other than a competent person taking charge of operations.

8. The entire operation is simple and effective when properly conducted.

9. Economy of operations is effected by several factors. Proper equipment and chemicals are necessary for effective disposal of unwanted and dangerous wastes. Added to this are requirements of time to be spent on this operation by individuals qualified to do the work. In no case is the operation an economical one unless considered as being more economical than a possible legal action resulting from indiscriminate disposal of poisonous materials, with resultant damage or possible loss of life to others. (Industry or industries employing chemicals as dangerous as cyanides in operations are faced with the responsibility of properly disposing of such poisonous wastes resulting therefrom without creating additional hazards to others. An effective disposal system, properly operated and maintained, can be considered in the public interest as well as effective insurance against possible complications of medical or legal character.)

10. An installation employing the process of chlorination has been proved to be entirely effective as a means of destroying cyanide wastes—when properly operated. Such an installation is probably the most economical; operations in it are the most positive of any investigated to date.

11. Chlorination to the point where cyanides are oxidized to cyanates is no insurance against absence of cyanides in solutions containing oily wastes. Complete chlorination to the point where free chlorine exists in the solution is double assurance of completed reactions.

12. Indiscriminate mixing of cyanide bath skimmings with similar wastes from nitrate baths is to be discouraged, due to the possibilities of reactions between materials of this nature. Reactions between materials of these types, when coming into contact while hot, have been known to cause dangerous explosions. The writer has been unable to find any authority which may point out the same conditions in water solutions of these materials when mixed. In any case, economy of treatment of such mixtures is seriously affected during disposal of cyanides by chlorination. Solution of such mixtures appears to be much slower that that of skimmings from unmixed cyanide baths. Sodium or potassium cyanides are quite readily soluble in water.

13. It is assumed that, when present accumulated materials are effectively disposed of, future operations will be

simplified if factors mentioned are given proper consideration. (Note: The foregoing was written on November 25, 1947. Since that date, the above assumption has been proved to be well taken.)

14. It is believed that education of personnel concerned with the handling of cyanides and cyanide wastes through a meeting or series of meetings may be of benefit in providing information of benefit in efficient disposal of such materials.

Since the start of operations, approximately 100 lb. of waste have been treated each week. Such wastes vary in cyanide content from as little as 3 per cent to as high as 60 per cent in cyanide content (as NaCN).

Subsequent Improvements

The accompanying photographs show progress made through study of the process, as well as indicated improvements in equipment. Figure 2 indicates the second step in the development of the Detroit Diesel Engine chlorination system. The chlorine cylinder had been moved several feet from the tank to minimize the possibility of splashing cyanide solutions on the surface of the cylinder. It was felt that cyanide on the outer surface of the cylinder might represent some possible hazard to anyone handling the cylinder after use for this purpose. The protective equipment by this time included a rubber raincoat for over-all protection against splashes.

A post had been set up and the chlorine cylinder chained to it for greater safety. Calcium hypochlorite was still being scattered on the ground in the neighborhood of the tank.

Later (Figure 3), the chlorination tank was relocated 60 ft. from the incinerator building and 40 ft. from a shipping dock. The tank was placed in an overflow pit designed to care for twice the volume of cyanide solution in the chlorination tank. The tank area

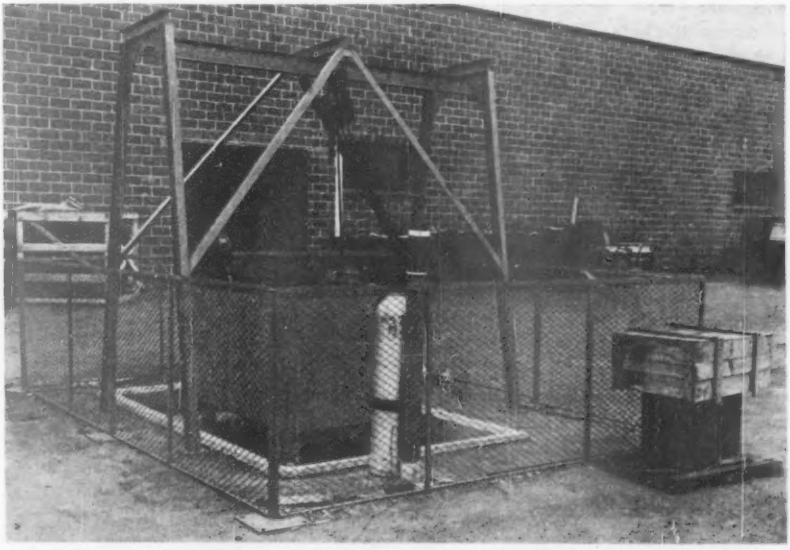

FIGURE 3.—Third step moved tank to overflow pit and provided guard fence and monorail hoist.

FIGURE 4.—Latest improvement provides additional safety features, special first aid kit, and redesigned cyanide waste containers.

was surrounded by fencing to keep onlookers at a safe distance, and dumping of cyanide waste into the tank was made easier and safer by the installation of a monorail hoist. The containers for cyanide skimmings and sweepings at this stage were used drums and were covered by the wooden box to prevent entrance of rain water. Because of the danger of inhaling powdered cyanides while dumping the cyanide wastes into the tank, the practice was adopted of wetting down the material before dumping. In cases where solid matter could not be removed from drums by the usual method, the chain hoist could be used to lower the entire drum into the tank. After the solid cyanide was dissolved, the drum was removed and rinsed off into the solution.

Present Installation

The present installation is essentially as previously described, with refinement of details. The outlet valve from the tank is a gate valve provided with a lock, the key for which is in the possession of the plant chemist and is released to the operator only after laboratory tests indicate the presence of free chlorine in the solution. The discharge line was originally connected directly to the sewer. This proved to be unsatisfactory because solid matter collected under the seat of the gate valve and permitted unobserved leakage of untreated solution directly to the sewer.

Figure 4 shows the present chlorination setup at the Detroit Diesel Engine Division. The cyanide containers shown were constructed especially for this purpose and each has a small section of angle iron welded along one side to act as a rest against the tank edge while the material is being dumped. This is illustrated in the container on the left. Note the precautions taken to advise bystanders of the poisonous nature of the cyanide.

The sewer connection from this tank

can be broken at the outlet side of the valve by opening a common pipe union. The line is also normally disconnected from the sewer pipe and capped on the end. Any leakage from the discharge valve goes directly to the pit under the tank and is pumped back into the tank for treatment. A first aid kit was provided in case of emergency and is stocked with those special materials required for treatment of cyanide poisoning. Covers are provided for the cyanide containers to eliminate any possibility of overflow from heavy rainfall. These containers are handled by fork-type lift trucks.

The chlorine line now contains a check valve and a vacuum breaker. The only control exercised over discharge of chlorine from the cylinder is observation of the frost line on the cylinder.

The tank is used also for cleaning broken cyanide pots before disposal, and to clean cyanide pots being sent for repair.

The containers shown in Figure 5 illustrate the method used by some organizations for handling solid cyanide waste. This method was considered highly unsatisfactory and unsafe due to the danger to employes in attempting to handle drums and to remove cyanide from the drums. These containers have been replaced by those shown in Figure 4.

In the present installation, personnel need not contact cyanide wastes. All handling is mechanical. All wastes of this nature, regardless of source, are treated by chlorination. Even scrap pots containing cyanide residues, as well as usable pots and brick work which may have cyanide residues, are treated in the setup pictured before handling by workmen. Original containers in which cyanide salts are obtained are destroyed when empty. Waste plating baths and solutions from exhaust pans are treated. No cyanide is permitted to leave the plant in any form.

The rules for operation now in effect are given in Figure 6.

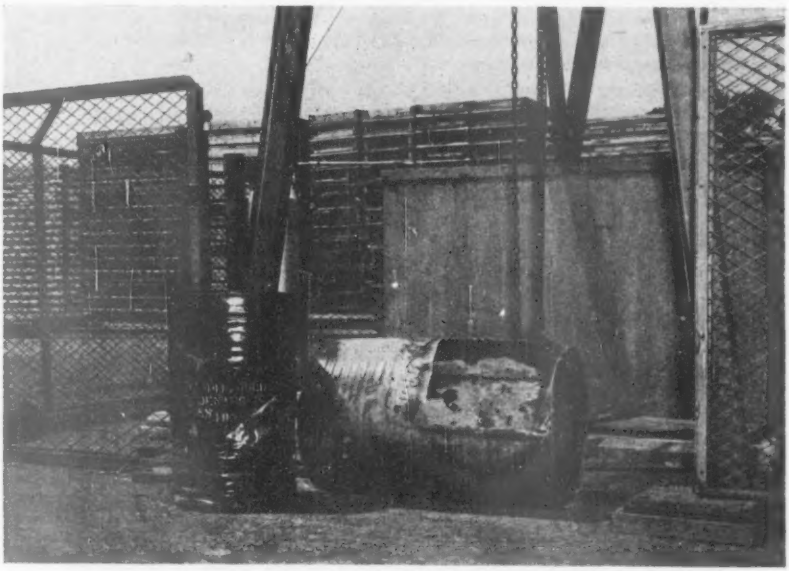

FIGURE 5.—Unsafe type of container for solid cyanide wastes.

DISPOSAL OF CYANIDE WASTES BY CHLORINATION

This process consists essentially of the addition of chlorine gas to solutions of cyanide wastes such as pot skimmings from heat treat operations, discarded plating baths, rinse waters, and cyanide residues from any source in the Plant. All wastes are dissolved in water in the treating tank. Wet dry materials thoroughly before dumping into treating tank to prevent dusting. The pH of the solution must be held above 8 and the temperature must not exceed 120° F. during operations.

CAUTION

BECAUSE OF THE EXTREMELY POISONOUS NATURE OF THE CHEMICALS USED IN THIS PROCESS, ONLY QUALIFIED PERSONS MAY BE PERMITTED TO CONDUCT OR SUPERVISE OPERATIONS INVOLVED

RULES OF OPERATION

1. Every effort must be made to avoid personal contact between individuals and contents of tank or containers.
2. Should contact be accidently made, all persons making the same must wash points of contact immediately with running water.
3. The tank in which the process is conducted must be free from residual materials before adding new materials to be treated. Connections between sewer and treatment tank must be disconnected and outlet valve closed before adding charges.
4. All individuals engaged in operations must wear such clothing and protective equipment as approved by the Safety Department.
5. Chlorine additions may be made only when the treatment tank is filled to the proper operating level with solution. The solution must be stirred while chlorine is being added.
6. Chlorine gas will be added only by a qualified individual authorized to do so. Additions will be continued until free chlorine exists in the solution as determined by the Chemical Laboratory.
7. No solutions will be dumped until permission is obtained from the Chemical Laboratory after submission and test of a sample from the well-stirred solution.
8. Waste materials in miscellaneous containers will not be accepted for treatment. Cyanide wastes must be submitted in containers specifically designed for such materials.
9. Only Chemical Laboratory tests will be accepted as evidence of materials treated. No other Department nor individual may authorize dumping of solutions.
10. Unauthorized individuals must not be permitted at or near operations at any time.
11. Operations must be conducted at sufficiently frequent intervals to assure the availability of an empty tank or container for heat treat use.
12. All containers must be rinsed into the treating tank before return to the heat treat. Tanks must be dry before skimmings are placed in them.

FIGURE 6.—Operating rules for disposal of cyanide wastes by chlorination.

III. PONTIAC MOTOR DIVISION

By Earl J. Roy

Chief Chemist, Pontiac Motor Division, GMC, Pontiac, Mich.

In 1949, it became necessary for the Pontiac Motor Division to dispose of a considerable amount of wastes containing a high percentage of cyanide. These wastes came from the heat treat, copper plating, and zinc plating systems.

A 2,400-gal. tank was set up with mixers for agitation and some pipes across the bottom. Small holes about 6 in. apart were drilled in these pipes so that chlorine could escape through the holes during violent agitation by the mixers. However, this was not successful, being too slow and allowing some chlorine to escape into the air, causing a nuisance. Also, the holes plugged easily. Various arrangements of pipes and agitators did not remedy the condition.

The next move was to install a sump pump at one end of the tank to circulate the solution while chlorine was introduced at the suction end. The outlet side of the pump was attached to a 2-in. coil approximately 30 ft. long, the solution being exhausted back into the tank. This worked out quite satisfactorily, except that all the cyanide waste could not be treated as fast as produced. Therefore, it was decided that if a certain amount of waste could be treated with one pump, two pumps would treat twice as much and another sump pump was installed at the other end of the tank.

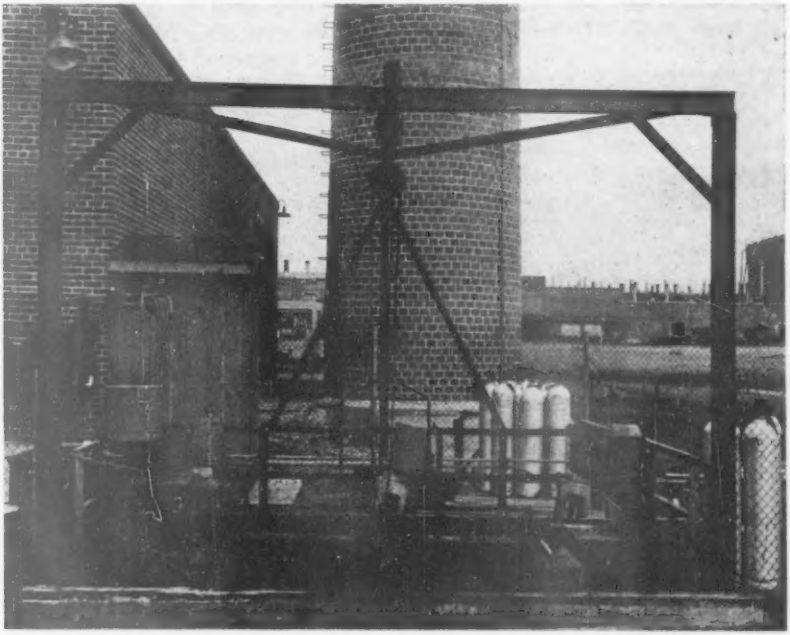

FIGURE 7.—Cyanide waste chlorination equipment at Pontiac Motors Division.

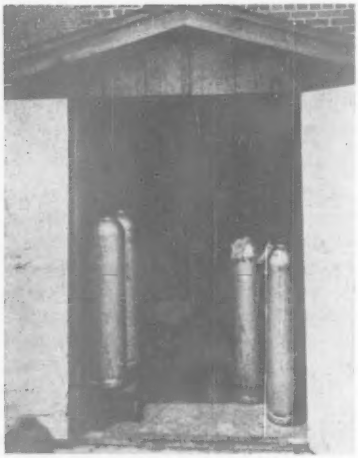

FIGURE 8.—Chlorine house and hook-up.

The present setup now appears as shown in Figure 7. The tank, approximately 15 ft. long, 8 ft. wide, and 38 in. deep, sits in a concrete-walled pit large enough to permit working space at one side and at each end. The tank holds 2,400 gal. at working level. At each end is a sump pump of 150-g.p.m. capacity. Each pump exits through a 30-ft. long 2-in. coil. A 2-in. pipe, approximately 18 in. long, is attached to the inlet of each pump, to which is attached a ¾-in. chlorine feed line.

The three agitators are impeller-type mixers and are used to speed solution of sludges. A large screen-type basket is used to retain coarse, insoluble material. Two 5-in. valves permit draining the tank to the sewer when the reaction is completed. The valves are locked to prevent unauthorized opening. The key is kept in the laboratory and given to the operator by the chemist or his assistant only after chemical analysis shows no cyanide to be present.

The cyanide content of the waste when diluted and/or dissolved in the tank solution varies from 1,000 to 14,800 p.p.m. (as CN). The length of time to treat the solutions varies, of

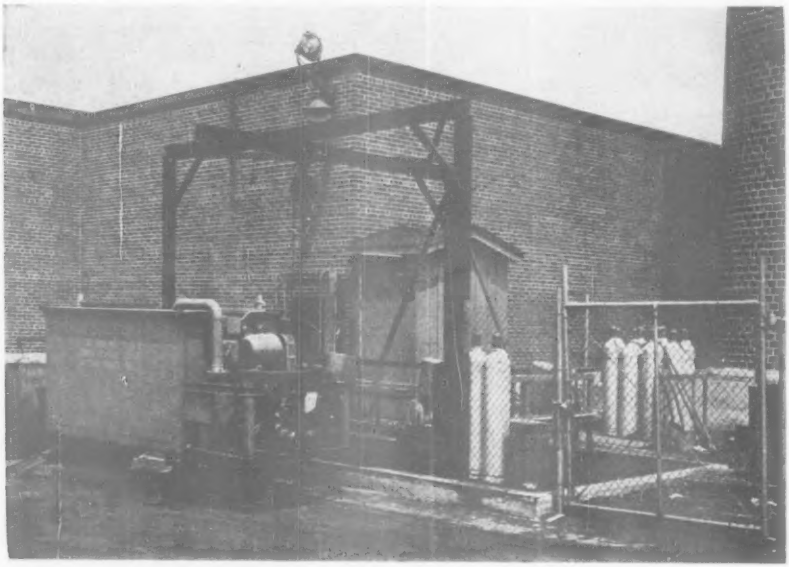

FIGURE 9.—Mobile waste plating solution tank and pump outfit.

course, with the concentration of cyanide. The 14,800-p.p.m. solution required 48 hr. to destroy the cyanide.

Figure 8 is a view of the chlorine tanks, the house for protection from the weather, and the connections to the chlorine pipes leading to the pumps. The flexible hose is thick-walled air hose. A platform scale is used to weigh the chlorine tanks to indicate when they are empty. An electric heater with thermostat has been installed to take off some of the chill in winter weather. A pet-cock installed in each chlorine line is opened when the system is shut down.

The type of tank used to transport the waste copper plating solution to the disposal tank is shown in Figure 9. Particular attention is called to the sign on the side, which reads: "Cyanide solutions only—this tank not to be dumped anywhere except in cyanide disposal tanks." The four-wheel truck carries the 1,000-gal. tank and a pump for filling it; a large valve is provided to drain the waste solution to the disposal tank. The truck is moved by attaching it to a small industrial-type tractor.

Figure 10 is a view of the heat treat waste disposal tub. The tub tapers from 22 in. square at the top to 20 in. square at the bottom and is 30 in. deep. The lugs on the sides of the tub are provided for lifting and dumping by the hooked fork and chain hoist. The center of the lugs is 16 in. from the tub bottom. The cover prevents the tub from being used as a catch-all and keeps out rain or snow.

The waste put into the tub is dry spent cyanide waste and slightly oily sludge from the cyanide hardening quench tank. Sludge from the zinc plating systems is transported in a V-shaped sludge wagon of approximately 300-gal. capacity.

FIGURE 10.—Heat treat waste disposal tub.

Amounts of Wastes

Amounts of waste to be destroyed include—300 lb. per week from heat treat, 300 gal. every 2 to 3 weeks from zinc plate, and 4,000 gal. copper solution every 3 weeks.

The amount of chlorine used to react with the cyanide has varied from 3.25 lb. of chlorine to each pound of cyanide (CN) for heat treat waste to 7.58 lb. of chlorine for copper plating waste. The caustic varies according to the alkalinity of the waste at the start, but has been as high as 6.3 lb. added for each pound of cyanide (CN).

Chemical analysis is made for pH and cyanide at the beginning of each batch and then periodically as experience has indicated to be necessary. For the copper and zinc plating wastes, the total cyanide is determined by distillation of the cyanide using magnesium chloride and sulfuric acid. The cyanide is collected in a caustic solution and then titrated using the modified Liebig method.

There are certain advantages to this method of disposal. The principal one is that high cyanide content wastes can be chlorinated and flushed down the sewer.

However, there also have been some difficulties. The first sump pump was

a used one that the Maintenance Department had in stock and it worked well. When the second pump was installed, however, it didn't do so well as it would form a gas lock when the chlorine was turned on, and quit pumping. This was because the new pump had a closed-type impeller, whereas the older one had an open-type impeller. The difficulty was overcome by drilling two ⅜-in. holes in the bowl of the pump. Although the two pumps are rated at equal capacity, the open-type impeller pump requires less maintenance, as it is less subject to plugging. The tank requires frequent cleaning of copper and zinc sludges, for which it takes two men about 1½ hr. The chlorine inlet pipes have to be inspected and changed frequently.

The initial cost of this setup was approximately $6,000.

IV. DELCO-REMY DIVISION

By C. F. Hauri

Plating Engineer, Delco-Remy Division, GMC, Anderson, Ind.

This paper relates the experiences of the Delco-Remy Division of GMC in determining the practicability of the destruction of cyanide in the after-plating cycle of a plating machine. At the 1948 Industrial Waste Conference held at Purdue University, this Division outlined its procedures and methods of control of cyanide wastes. The principal points covered in that presentation (1) were:

1. The plant management had changed the definition of "sewer" from "a place to get rid of something" to "a place where you cannot get rid of anything."
2. The plants were built and operating before any thought was given to waste disposal. Consequently, a waste disposal plant for the treatment of rinse waters is a practical impossibility.
3. A program was described for the destruction of all cyanide wastes other than rinse waters.
4. A reclaim procedure was described for minimizing the introduction of cyanide into the sewers.

The principal waste which the plating man has been concerned with is cyanide. With the above program in operation, thought was turned to ways and means of further reducing the cyanide content of the sewer effluent with the ultimate aim of the return of the used water in as near the original condition as possible. The work previously done could be considered as mechanical methods of preventing contamination and these seemed to have been carried as far as possible. Therefore, the only alternative seemed to be chemical destruction of the unavoidable contaminations of cyanide.

Of course, the traditional method of accomplishing these results is the construction of a basin or holding tank where all waters can be treated to eliminate the undesirable constituents. This has been previously mentioned as being impractical in the case under discussion.

The only other possible approach was to destroy the cyanide in the rinse water before it went to the sewer; in other words, as part of the rinsing cycle, after plating. The best method for destruction of cyanide was considered to be alkali chlorination. Accordingly, chlorinated lime was added to a rinse after plating in a preliminary experiment to observe the effects on plated work, equipment, etc. No adverse effect was noted.

From these experiments it was decided to try the destruction of cyanide carried from an automatic barrel zinc

plating tank and which had passed through two reclaim stations. Being an automatic operation, it was necessary to constantly feed chlorine; in this case, the only practical procedure was to use liquid chlorine.

At first thought it might seem that very little apparatus or equipment would be necessary for chlorination of waste waters. However, investigation revealed that chlorination of water was not quite as simple as had been imagined. Due to the limited solubility of chlorine in water it is necessary thoroughly to disperse chlorine gas by means of suitable apparatus and methods into the liquid to be chlorinated. Also, two other factors had to be taken into consideration:

1. An excess of chlorine which would be liberated into the atmosphere if chlorine were simply bubbled through water. This must be avoided for economic reasons.

2. Any chlorine escape into the plant was intolerable.

Any of these three reasons would make a chlorination machine mandatory. Accordingly, the purveyors of chlorinating equipment helped in the selection of a 100-lb. per day commercial chlorinating machine, a 600-g.p.h. circulating pump, and an indicating pH meter.

The plating operation upon which the method was to be tried was zinc plating, which contained 5 to 5½ oz. per gal of zinc, 13 to 16 oz. per gal. of

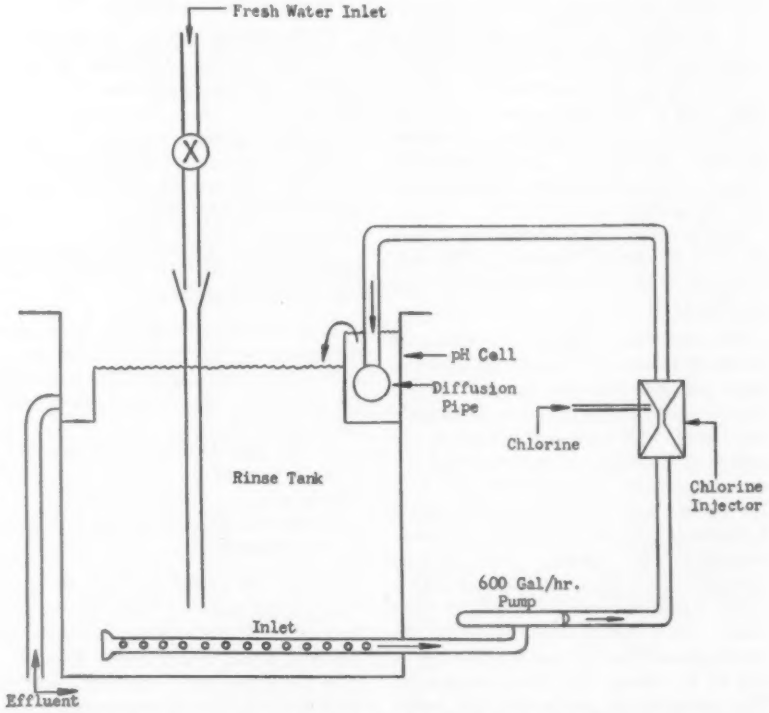

FIGURE 11.—Flow diagram for chlorination of cyanide in rinse tank of plating machine.

sodium cyanide, and 12 to 14 oz. per gal. of caustic soda. Approximately 1,500 sq. ft. of surface area per hour are plated in the machine. There are two reclaim tanks, the first of which is run empty so that plating solution can drain from the work tumbling therein. The other, originally contained water, but gradually built up in cyanide content until such time as it was returned to the plating tank, when it was again filled with water. Tests on the rinse tank following these two reclaims showed 200 to 400 p.p.m. of sodium cyanide with a 15 g.p.m. water flow.

It was decided to try the chlorination of this rinse following the two reclaims. So that it would be suitable for this procedure, the tank was altered as follows:

1. Suitable ventilation was added.
2. A bottom outlet was provided for connection to the chlorinator intake.
3. A sump was provided for the return feed of the chlorinator. This was made in the rinse tank and overflows thereto. Its purpose was to cause diffusion and to house the electrodes of the pH meter.
4. The pump was inserted in the inlet line to the chlorinator. The flow diagram of the altered process is shown in Figure 11.

In operation, the rinse water is pumped from the tank to be chlorinated through the injector of the chlorinator machine. The flow is greatly restricted while passing through the orifice of the injector and the resultant vacuum draws the chlorine gas into the stream and also results in a great turbulence, which helps the solution process. The stream, after passing through the injector, is returned to a diffuser placed in the sump of the rinse tank. This sump also contains the electrodes of the pH meter, which consist of an alarm and visual indicator. The operation is continuous, the water in the tank being constantly recirculated during operation. Fresh water is added to the rinse tank at a rate of about 1 g.p.m., so that a like amount overflows continually to the sewer. The chlorine feed can be adjusted from 0 to 100 lb. per day, the capacity of the machine. With present operation, the adjustment is made to about 80 lb. per day and the alkalinity is adjusted by adding caustic soda to maintain a pH of 8.5 to 10. About 2 lb. of caustic soda per hour is so used. The value of 80 lb. per day was arrived at by finding the average needed to maintain free chlorine in the sump. The presence of free chlorine in the sump compartment is deemed to be a suitable indication of the absence of cyanide; however, cyanates are satisfactory for the purpose. The check for presence or absence of free chlorine can be made at the machine as follows:

1. Use about 100 ml. of sample.
2. Add one or two drops of methyl orange indicator solution (avoid an excess).
3. Stir. Disappearance of color indicates presence of free chlorine.
4. The pH must be in the range of 8.5 to 10 for this test.

Batch-type operation of this equipment is believed to be the most practical for three reasons.

1. The hardness of the water used makes an enormous amount of insoluble calcium salts, as caustic soda must be added in greater amounts when more water is used.
2. The possibility of chlorinating a rinsing flow of 15 g.p.m. is problematical.
3. Maintaining the correct pH would be a problem.

Before the equipment was in operation, it was thought that the chlorination of the rinse could proceed for perhaps 4 hr., followed by discarding it to the sewer and recycling. Experience with the actual equipment caused a decision to allow an overflow of 1

g.p.m. by the addition of fresh water, thus theoretically turning over the solution every 2 hr. This makes it unnecessary to discard and results in less down time for the plating operation.

No effort is made to explain herein the chemistry of cyanide chlorination, which is outside the purview of this paper.

The cost of all new equipment was approximately $3,000. The chemical cost of operation is about $0.50 per hour.

In conclusion, it may be stated that:

1. It is possible to destroy cyanide in the cycle of a plating machine.

2. Apparently, the process described herein is a minature disposal plant attached to a plating machine.

3. Due consideration should be taken of the hazard of chlorine in a plant.

Reference

1. Kessler, R. L., and Oyler, R. W., "Methods of Disposing of Cyanide Wastes." *Eng. Bull.*, **33**, No. 4 (Extension Series No. 68), Purdue Univ. (July, 1949); abs. THIS JOURNAL, **22**, 10, 1381 (Oct. 1950).

DECONTAMINATION OF RADIOACTIVE WATER

One of the problems confronting civilian defense agencies is that of providing safe drinking water following an atomic bomb blast. The recognition of this problem has led to development and testing by the Health Physics Division of Oak Ridge National Laboratory of a water decontamination unit, which can effectively meet the need.

Preliminary data indicate that a water containing at least 1 microcurie (μc.) per ml. of mixed fission products (2×10^6 disintegrations per min. per ml.) can be treated in a compact and relatively inexpensive unit to produce a drinking water with activity of less than 10^{-4} μc. per ml. This level of contamination is well below that considered by many authorities to be safe for use under emergency conditions (10^{-2} μc. per ml.) that might result shortly after an atomic explosion.

The unit contains anion and cation exchange resins used in conjunction with other adsorbents found to be specific for certain isotopes, which normally leak through the ion exchange resins. In the initial test the water was pretreated to remove much of the calcium and magnesium naturally present in the water; about 80 per cent of the radioactivity was removed by this procedure. Twenty gallons of the supernatant liquor, containing about 0.2 μc. per ml. of β radiation, were passed through the two-column unit before the activity of the effluent exceeded 10^{-4} μc. per ml. More recent tests, not yet completed, have shown that the water can be passed directly through the unit without pretreatment, although a slower flow rate may possibly be needed and the capacity of the unit may be somewhat lower.

CHEMICAL ENGINEERING ASPECTS OF INDUSTRIAL WASTES CONTROL *

By C. Fred Gurnham

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The treatment and disposal of municipal sewage has always been considered to be a task for the sanitary engineer. As the importance of industrial wastes has become recognized, their treatment also has been assumed by the sanitary engineer because of the numerous points of similarity to sewage treatment and because of the sanitary engineer's familiarity with these processes and with the design of structures required in the treatment.

The processes used in the treatment of sewage are both chemical and biological in nature. As examples of the former, there may be mentioned pH adjustment, chemical precipitation and coagulation, and chlorination. In the disposal of trade wastes, the chemical features become more pronounced and there is a distinct field for the chemical engineer. In particular, when industrial plant processes must be studied in order to attack the waste problem at its source, the chemical engineering approach is a necessity.

It is apparent, therefore, that in the study of the treatment and disposal of industrial waste waters, there is need for cooperation between the sanitary engineer and the chemical engineer. It has been pleasing to note, especially during the past decade, an increasing interest in this field on the part of the chemical engineer, and an increasing willingness to accept this interest by the sanitary engineers, who undoubtedly have priority rights to the field. To illustrate the former, there should be mentioned the active committee of the American Institute of Chemical Engineers on industrial wastes, as well as several symposia on industrial wastes which have been sponsored by the American Chemical Society and presented in *Industrial and Engineering Chemistry*.

Herein it is proposed to discuss some of the fields where chemical research on waste treatment processes is active, and to name some chemical processes and operations having possibilities for wider use in this field. No attempt is made to discuss the biological processes, although the two subjects are not separate and distinct, and there is a great deal of overlapping.

Unit Task Concept

The chemical engineer, several years ago, classified his tasks into a series of "unit processes" and "unit operations," to aid in studying the very broad field of chemical technology. A "unit process" is a type of chemical reaction, and may be employed in any number of distinct industries. As an example, there is the unit process of oxidation, which includes the oxidation of sulfur as the first step in sulfuric acid manufacture, the oxidation of naphthalene to phthalic anhydride to be used in the manufacture of dyestuffs, the oxidation of fuel in a boiler furnace, or any of a multitude of other chemical oxidations.

The "unit operation" is a similar concept, applied to a physical instead of a chemical change. Thus, filtration is a unit operation, which is utilized in

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the manufacture of sugar, in the clarification of rayon solutions prior to spinning, in the concentration of a digested sewage sludge, in the recovery of chemical crystals or precipitates, and in the manufacture of countless other chemical and industrial products. The chemical engineer claims these unit operations and unit processes as his own domain, although many individual applications were in use for years before chemical engineering was thought of as a profession; at least the chemical engineer has done much to investigate these operations and processes, and to render them useful concepts for plant design and operation. Examination of some of these unit processes and unit operations from the viewpoint of their application to industrial waste treatment should prove interesting.

The types of waste best adapted to chemical treatment are those from the inorganic process industries; for example, from the metal industries, the electrolytic industries, and the manufacture of acids, alkalies, salts, and other inorganic chemicals. This is a broad field producing wastes that are especially objectionable from the standpoint of toxicity and sludge formation, although first place is conceded to the organic industries for production of B.O.D. Even in the organic field, chemical treatment is frequently desirable, either as an adjunct to biological treatment or alone. In the inorganic field, however, chemical treatment is often the only possible means of processing.

Oxidation

As oxidation has already been mentioned as a typical unit process, its application in waste treatment should be considered. The principal action of activated sludge and the trickling filter is one of oxidation; however, because this oxidation is carried on, or catalyzed, by bacterial organisms, it will be conceded to the realm of biological rather than chemical treatment. Certainly there is room for cooperation in these studies, and the chemical engineer should have much to contribute to an understanding of these processes and to their improvement. Much recent progress in the chemical field has centered on biological processes, such as the manufacture of butyl alcohol, acetone, citric acid, and other chemicals by fermentation, and the production of penicillin, streptomycin, and the other anti-biotics. As the chemical engineer acquires more familiarity with these processes, he will be able to contribute more to the knowledge of biological oxidation of wastes.

Another oxidation reaction of interest in the industrial waste field is the destruction of cyanides from electroplating and metal treating shops and from certain chemical industries. Cyanides are an objectionable constituent of wastes because of their high degree of toxicity; several state agencies have limited the cyanide content of streams to well under 1 p.p.m., and the permissible concentration in municipal sewers is also low. There are a number of processes used for destroying cyanide in waste waters, but the most popular one at present is based on oxidation of the cyanide with chlorine. Several plants employing this process are in operation at the present time, ranging in size from a capacity of about 1 lb. of cyanide destroyed per day up to plants treating over 100 lb. per day. The process has been described in a number of technical papers, but is still imperfectly understood; research in this field is active at the present time, by the American Electroplaters' Society and others. The reaction apparently takes place in two stages—the first, a rapid oxidation of cyanide to cyanate; the second, a slower reaction ending with the formation of carbon dioxide and ammonia. In some installations, the first stage may comprise sufficient treatment, but

usually complete oxidation is required by the authorities. It may be economical, in large plants, to utilize only the first stage of this reaction, and then to destroy the cyanate by some other reagent than chlorine. However, further studies are needed on this process. A comprehensive research program on the chlorination process for oxidizing cyanides is nearly completed at this time, and will be reported in the journals of the American Electroplaters' Society before the end of this year.

Other oxidation agents for cyanides have been suggested, but most of them are more expensive than chlorine. These include permanganates, peroxides, ozone, chlorine dioxide, and others. A recent patent suggests the use of air, in the presence of certain common catalytic agents in the solution. If this process proves feasible, it should certainly be cheaper than the use of chlorine. However, no further details on the process have been seen, and attempts to duplicate the results described in the patent have not been encouraging.

In discussing oxidation, mention should be made of combustion, which is a form of complete oxidation. Several wastes have been treated by this process, after evaporation of water to the point where combustion can take place. It is apparent that only concentrated wastes are suitable for such treatment. Cyanides in spent plating baths and in molten salt baths have been treated in this manner. Cooking liquors from the paper pulp industry are regularly recovered by this process, the alkali being recovered as soda ash and the sulfur compounds as sodium sulfate or sulfide. A similar process might be suitable for certain textile and tannery wastes, with recovery of useful chemicals. The process is also suitable for other strong organic wastes, which can be evaporated to the point where they will support their own combustion.

Reduction

The reverse unit process from oxidation is reduction, and this, too, is sometimes useful in the treatment of industrial wastes. The best known example of this is in the handling of chromate wastes, which occur from chrome plating, from the anodizing of aluminum, from leather tanning, and from some chemical plants. Chromium in the trivalent (or reduced) form can be precipitated along with other heavy metals by alkaline agents and so removed from the waste. However, if the chromium occurs in the hexavalent (or chromate) form, such treatment has no effect. Accordingly, it is standard practice to reduce the chromate to trivalent chromium using any of a number of chemical reducing agents, the most common of which are ferrous sulfate (copperas), various sulfides and sulfites, and gaseous sulfur dioxide. The last named is becoming the most popular because of its ease of handling and because it forms less sludge than the other reagents. With these advantages, the use of sulfur dioxide may actually be more economical than the "cheaper" reagents, such as copperas. This reaction is being utilized in several plant-scale installations at the present time, although there is undoubtedly room for improvement in the operating practice. A newer industrial chemical now undergoing test as a chromate reducer is sodium metabisulfite ($Na_2S_2O_5$), which contains 65 per cent available sulfur dioxide, and is a free-flowing crystalline solid. This material may become very useful in this application.

Another well-known reduction process is the removal of copper from copper-bearing wastes by treatment with scrap iron metal or brass. This is a common practice for treating pickle liquors from copper and brass mills. The iron is employed in the form of chips or turnings in a stationary bed, through which the copper waste per-

colates. The copper salts are reduced by the iron or by the zinc in the brass scrap to metallic copper, which is deposited in the bed and can be recovered if the quantity is sufficient to make it economical. Of course, the iron or zinc is simultaneously oxidized, so that iron or zinc salts are present in the effluent liquor; the iron is relatively harmless and is easily removed, the zinc is frequently worth recovering.

In discussing oxidation and reduction processes, it is appropriate to mention sulfur, which occurs in a number of states of valence, including sulfides, elemental sulfur, sulfites, and sulfates, as well as other combinations. Some of these are objectionable, and because change from one state to another is fairly easy, the elimination of sulfur troubles may be difficult.

Neutralization

A third unit process frequently used in waste treatment is that of neutralization. By this process, harmful acid wastes can be treated with alkali, or harmful alkaline wastes with acid, to produce a relatively innocuous neutral salt. Sometimes both acid and alkaline wastes occur in the same plant and can be used to neutralize each other, usually with the requirement of additional acid or alkali to make up whichever one is deficient in quantity. An outstanding example of this is the plant of the American Cyanamid Company at Bound Brook, N. J., which produces a large quantity of acid waste from chemical manufacture. This plant brings in, by pipeline, alkaline wastes from the nearby Johns-Manville Plant, and the two wastes, each harmful by itself, successfully neutralize each other to a harmless effluent.

Such examples of proximity of acid and alkaline wastes are not as common as could be wished, and it generally is necessary to furnish a reagent to effect the neutralization. There is a wide variety of reagents available, so that the choice may be made on the basis of price and other economic factors, as well as suitability for the specific purpose.

The Iron and Steel Institute has been working on the neutralization of acid pickle liquors for several years, and has made considerable progress in this field. If cost could be ignored, there would be no problem in this treatment, but such an assumption is not very practical. Accordingly, much of the research has been directed toward utilization of the cheaper, and generally less satisfactory, alkaline reagents. Some of the difficulties encountered with these are a slower reaction rate, coating of the reagent particles with reaction products so that the neutralization is not completed, and the need for good contact between the reagent and the waste. Among the reagents used for this reaction are: the sodium alkalies, lime, limestone, dolomite, various alkaline slags, and alkaline waste products from other industries.

The neutralization of acid plating wastes is a frequent requirement. In the typical job plating shop, these are not usually present in large amount, so it may not be essential to use the cheapest reagent. This is important, because sometimes the more expensive reagents are economical for other reasons than price, particularly in the smaller companies. Thus, limestone is rarely used, in spite of its cheapness, because of the slowness of the reaction, and because the stone particles become coated with a layer of calcium sulfate and metal hydroxides, which stops further action. Lime is more satisfactory than limestone in both these respects, but still requires vigorous agitation to obtain reasonable reaction rate and thoroughness of the reaction. Soda ash is much more convenient, and is the most common reagent for this work, in spite of its higher price. It can be fed to the waste in solution form, so that it is easily mixed

with the waste and its rate of addition can be controlled readily by means of an automatic pH regulator. The use of soda ash leads to less sludge formation than the lime reagents, and this may be an important economic advantage.

Acid wastes occur from the manufacture and treatment of metals as mentioned above, also from many chemical industries and a number of the organic industries. Alkaline wastes are perhaps less common, but may be strongly polluting, as witness the wastes from paper pulp manufacture, wool scouring, cotton kiering, and the like. In some of these plants, the alkali can be recovered economically; in others, it must be neutralized with sulfuric or other acid, or sometimes by treatment with flue gas, which contains carbon dioxide, an acid gas.

Electrolysis

Electrolysis is a unit process that has not been used much in waste treatment, although there are a few specific applications. It provides a means for destroying cyanide in concentrated form, as in spent plating baths, and has the considerable advantage that the process can be utilized in the existing plating tanks with equipment already on hand in the plating shop. Furthermore, it is a process similar to those with which the plant operators are familiar.

Electrolysis has also been suggested as a means of producing floc, but the applications of this for waste treatment probably are limited. This process probably will be more useful as a means of purifying water.

Double Decomposition

Double decomposition reactions are the basis of most of the precipitations of metallic wastes, as well as for the formation of flocs in the conventional chemical coagulation of sewage and industrial wastes. For example, the reaction of an iron salt and lime may be written as:

$$2FeCl_3 + 3Ca(OH)_2 \rightarrow 2\ Fe(OH)_3 + 3CaCl_2$$

The ferric hydroxide is not soluble in water, and so is precipitated. This precipitate is in the form of a floc, of valuable adsorbent properties, and hence the reaction is of value in the clarification of sewage and other wastes.

In the treatment of metallic wastes, most of the metals can be precipitated by double decomposition reactions of their solutions with alkaline solutions such as caustic soda or lime. For example:

$$CuSO_4 + 2NaOH = Cu(OH)_2 + Na_2SO_4$$

In this reaction, the copper hydroxide formed is precipitated and may be removed by settling or filtration; the sodium sulfate is harmless. Some excess of reagent is generally used to insure complete reaction, but with proper control this excess need not be harmful.

The specific case of chromium has already been discussed: in the chromate form, it is not precipitated by alkalies, but if first reduced to a chromic salt, such as chromic sulfate, a double decomposition reaction can be carried out leading to the precipitation of chromic hydroxide. A less popular reaction for chromate, but one which is in use to some extent, is the precipitation of barium chromate by double decomposition reaction with barium chloride or other soluble barium salt. This avoids the reduction step and gives a satisfactory removal of chromate. However, the reagent is expensive and is itself toxic, so the excess must be removed in a later step.

Another double decomposition reaction to be noted is the treatment of cyanides with acid, with evolution of hydrogen cyanide gas into the air. This process has been installed in a number of plants, and is a satisfactory means

of reducing the cyanide content of concentrated wastes, except for the psychological, and possibly the physiological, effect in populated areas. It should be noted that the useful double decomposition reactions are those in which one of the products is removed from the solution, either as a precipitate (for example, the copper hydroxide) or as a volatile material (such as the hydrogen cyanide).

Halogenation

Chlorination might be considered as one phase of the unit process halogenation, but in waste treatment work it is more properly a branch of oxidation, and has been discussed in that section. It is preferred to reserve the term "halogenation" for reactions where the chlorine (or other halogen) enters the molecule of the substance being treated. Perhaps this does happen in those processes already discussed, such as the chlorination of cyanide, but the chlorinated products decompose immediately so that the observable result is an over-all oxidation with chlorine, not a halogenation.

There is at least one true halogenation reaction of interest in waste treatment, but it is one which it is wished did not occur. Maybe it will be a chemical engineering problem to find a means of repressing this undesirable reaction, which is the formation of chlorophenols when wastes containing phenols, cresylic acids, and similar compounds are chlorinated. Everyone is familiar with the objectionable tastes produced in water by traces of these chlorophenol compounds, and the difficulty of removing them.

Ion Exchange

The ion exchange process has been suggested for a number of waste treatment applications, but is not extensively used as yet. Theoretically, it provides a good means of concentrating ionic materials in solution form; practically, there are several difficulties in applying ion exchange materials to a mixed waste. The process is being used to recover precious metals, such as silver and gold, from plating rinses and wastes. As further experience is acquired, it may become useful and economical for other metals as well, such as copper, nickel, tin, chromium, and others.

Ion exchange processes may have some promise for recovering alkalies from spent textile and other wastes, but the difficulty so far has been to obtain a resin or zeolite which will not be corroded or decomposed, or at least inactivated, by the alkali. Similarly, chromate recovery has not generally been successful because of the strong oxidizing effect of chromate on the resins.

It may be possible to recover some dyestuffs, especially the direct dyes, by ion exchange procedures. If successful, this could lead to economies in dye use in the dyehouse, as well as decrease in the amount of waste requiring treatment. No knowledge is had of any experimental work in this field, but the suggestion has been made and is certainly worth investigating.

Other Unit Processes

The chemical engineer also claims fermentation as a unit process, but, as far as waste treatment is concerned, this will be left to the biologist and the sanitary engineer. Perhaps, however, the chemical engineer may be able to contribute in some measure to the knowledge of activated sludge, trickling filters, sludge digestion, self-purification of streams, and the other biological processes of waste treatment.

The unit process pyrolysis has been discussed briefly under oxidation and combustion. However, pyrolytic reactions usually involve heating in the absence of air, or at least with a scant supply of air. Many organic wastes, after evaporation or drying, serve as reducing agents under these conditions. This may lead to useful reac-

tions, such as the regeneration of recoverable sodium sulfide from the waste liquors of sulfate paper pulp manufacture.

Unit Operations

Because it is concerned principally with the chemical aspects of waste treatment this paper places less emphasis on the unit operations than on the unit processes. There are, however, a few operations which should be mentioned because they offer opportunities that have been overlooked, or that have not yet been fully exploited in this field.

Evaporation has been mentioned already, as a necessary step in the concentration of wastes for further treatment. This is standard practice for many pulp mill wastes, and leads to recovery of the pulping chemicals. The principal objection to evaporation is the large heat requirement, which can be overcome in large installations by the use of multiple-effect evaporation. The recent development of compression distillation will bear study in the waste disposal field, as it provides a means for obtaining a large useful yield of heat by application of a moderate amount of mechanical energy. Another objection to the evaporation operation is the corrosive effect of some concentrated liquors on the equipment used. In this connection, it is worthy of note that one of the largest producers of glass-lined steel equipment is now supplying units for the specific field of industrial waste treatment.

Gas absorption has already been mentioned briefly in connection with the neutralization of alkaline wastes by treatment with carbon dioxide-bearing flue gases. Oxygen absorption by aeration is another phase of this unit operation, and the chemical engineer may have some information to offer here. Stripping, the reverse of absorption, is of interest in the treatment of cyanide by the acid process, as that reaction is accelerated and carried nearer to completion by blowing air or steam through the reaction vessel.

Solvent extraction is a unit operation which will have an increasing use in waste treatment, in such fields as the recovery of petroleum and other oils, wool grease, and similar materials, from the waste waters.

Adsorption is used to some extent, and will probably find wider application, in the recovery of valuable materials from wastes. A good example is the utilization of activated carbon in this field, although there are a number of other adsorbents which may prove valuable for this purpose.

Another operation which may deserve more attention than it has received is froth flotation. This operation is widely used in the mineral industries, and will probably have some applications in the treatment of trade wastes. The procedure involves treating the waste with a small amount of a special surface-active chemical, and then aerating to form a froth. The flotation agent produces a bond between specific solid particles in the waste and the air bubbles in the froth, so that these solids are separated in the froth phase from the bulk of the liquid. This operation will be most useful for recovering specific solid particles from a waste; for example, clay and carbon from paper mill de-inking wastes.

The foregoing list by no means exhausts the unit processes and unit operations of chemical engineering, but an attempt has been made to enumerate those most interesting in the industrial waste field, and to show what the chemical engineer is doing and can do in cooperation with the sanitary engineer. There should be more of this cooperation, which will work to the benefit of both groups and of the public.

Stream Pollution

WATER POLLUTION ABATEMENT IN THE UNITED STATES *

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The purpose of this paper is to summarize the present status of the water pollution problem in the United States and to discuss some of the responsibilities of the states and of the Federation in preventing pollution and providing for the best uses of surface streams. These topics are particularly pertinent after World War II, during which construction of new sewage and industrial waste treatment facilities virtually ceased. They take on added importance in view of the new defense-related problems now facing the nation.

In July, 1949, the Congress made the first appropriation to the Public Health Service to carry out certain provisions of the national Water Pollution Control Act of 1948, P.L. 845 (80th Congress). Under a plan developed jointly between the states and the Public Health Service, and in cooperation with other federal agencies, the Public Health Service has proceeded to assemble basic factual information about the water pollution problem facing the nation. The initial studies were not intended to be comprehensive. The gathering and utilization of such information, giving due consideration to all factors, will take a number of years. The first-stage objective was to assemble and analyze the vast resources of data readily available in the states, and from these data recommend immediate action programs. Summary reports based on these data will be published soon. Some of the preliminary national figures revealed by these studies will illustrate the problem, both in terms of what is now known and what is yet to be found out.

Size of Problem

There are 20,000 significant sources of pollution in the United States, about equally divided between municipalities and industries. The pollution load discharged to watercourses by 6,000 municipalities amounts to a population equivalent of some 30,000,000. However, for the remaining 4,000 municipalities, which serve nearly 40,000,000 people, data on pollution load to watercourses are either incomplete or not available. It is known that more than 5,000 of the 10,000 industries produce organic wastes. Of these, 2,000 produce wastes equivalent to a population of over 40,000,000. The other 3,000 plus industries produce organic wastes of which no measure is available.

In terms of over-all national needs, nearly 6,000 new treatment plants, replacements of existing facilities, or enlargements or additions are required. Some 1,000 municipalities, however, have not yet had their needs determined. Nearly 3,000 industries need new plants, replacements, enlargements or additions, but the needs of over 5,000 industries have not yet been determined. Such needs obviously

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must be determined in correlation with respective stream uses.

Costs Involved

Before estimating national expenditures required to correct pollution, let us look at what has already been spent. From 1915 to date, capital outlay for public sewage disposal construction has amounted to nearly $9,000,000,000, indexed to 1949 dollar value (1). During that period there was spent, in addition, more than $1,000,000,000 for maintenance and repair. To this $10,000,000,000 there must be added interest and operating charges to compute total expenditures. Comparable information on expenditures by industry for private treatment facilities are not currently available.

Municipal expenditure during 1949 totaling $277,000,000 is a gage of the steadily increasing public support of water pollution control, which support can be acknowledged only by continued progressive planning. The municipal sewage treatment investment for 1949 broke all existing records (2). On a physical volume basis, however, each dollar spent for sewage works brought only 85 per cent of what a dollar purchased during the highest prewar years. In the postwar period construction of municipal treatment works accelerated at a rapid pace. Twenty-three plants were built in 1946, 93 in 1947, 167 in 1948, and 208 in 1949 (3). These 491 new plants are serving more than 5,000,000 people.

Regarding future need, cost data resulting from the Public Health Service surveys have not yet been completed. However, an estimate based on a recent Twentieth Century Fund study of American capital requirements indicates that about $4,250,000,000 for municipal sewage treatment works is required to satisfy the more obvious needs by 1960. This estimate is based on the 1950 dollar value. Based upon the number of industrial plants and needs previously noted, a conservative estimate of an equal value for industrial costs is made. Thus, a total expenditure of more than $8,000,000,000 is indicated. A rate of expenditure nearly three times that of 1949, or about $800,000,000 annually, will be required if the goal is to be achieved within the 10-year time period.

Growth of Problem

It is sometimes difficult to view objectively the growth of the pollution problem in the United States. It is completely interrelated with the growth of the nation's cities and industries. The number of municipalities has more than doubled since the turn of the century. It has been customary to think of the United States as a large agricultural as well as industrial nation. Yet, today nearly 60 per cent of the people live in cities.

It is difficult to grasp fully the magnitude of the country's industrial growth. World renowned even in the 1920's, it has more than doubled since 1935, a mere 15 years ago. Leaders in government and industry foresee a continued annual increase in the industrial production capacity of this country. The increase in basic steel output that will come into production in 1952 supports this expectation.

The depletion of water resources for all uses, due to this tremendous growth, is well-known. Past action in this country has indicated an awareness of the problem by the public. The present critical stage of the problem is, on the other hand, a matter about which people in general are not aware. The race is against time.

National Policy

The national interest is reflected in the action of the Congress in passing the Water Pollution Control Act. Clearly stated in Section 1 of this Act is the policy of Congress to recognize, preserve, and protect the primary responsibilities and rights of the states in controlling water pollution. Con-

gress also recognized, however, that water pollution was not solely a state problem, but often interstate in character. The Act, in recognizing the primary rights of the states, sets up the means whereby the federal government can give the states financial and technical aid, and strengthen the over-all program through enforcement measures applying to interstate waters.

The Public Health Service believes that the policy established by Congress will work. The success of cooperative action depends largely, however, upon strong state programs. Historically, the policy of the Public Health Service has been to aid the states to that end. Much progress has been made in building up a friendly and cooperative relationship, for which a large share of credit is due the Conference of State and Territorial Health Officers, the Conference of State Sanitary Engineers, and other national organizations.

The present law limits federal enforcement to interstate problems with the consent of the state in which the problem originates. The burden of making this cooperative procedure work rests upon the states and the Public Health Service. The legislative history of the Water Pollution Control Act makes it clear that failure to accomplish adequate progress in pollution abatement through the cooperative efforts of the federal and state agencies will undoubtedly call for much stronger and more direct federal enforcement measures at some subsequent session of the Congress.

Three points for strengthening state action are:

1. State legislation.
2. State organization for pollution abatement.
3. Intergovernmental cooperation.

State Legislation

It has been said that the secret to successful prevention and correction of abuse of streams does not lie in the mere existence of comprehensive legislative enactments (4). With this point of view, the writer agrees, although he also believes that, everything else being equal, adequate state legislation is one of the principal bases for the successful operation of the control program.

State water pollution control legislation developed traditionally out of the authority of health departments to preserve public health. In conjunction with this there was piecemeal lodging of concurrent water pollution control authority in several other departments of state governments, such as those dealing with agriculture, fish and wildlife, and mines and minerals. The modern approach to the problem is reflected in recent state statutes, whose object is to preserve and improve water quality for all legitimate uses and do this through an agency that represents all affected interests in the state. Accompanying this has been a shifting of emphasis from the mere abatement of existing pollution to the policy of preventing pollution.

That the matter of legislation is of concern is shown by the fact that 25 states adopted new or strengthened existing legislation during the past decade. In 36 states, authority to control water pollution is divided among two or more state agencies. However, this division of authority does not appear to be too significant in about a third of these states, in which independent water pollution control authorities have been established. In these states residual powers remain in the health departments.

More than 20 states do not have what may be termed comprehensive water pollution control machinery. In other words, they have no law which provides for consideration of the interests of all water users, prohibits any geographical or functional exemptions, and provides adequate administrative machinery to effectuate water pollution control.

Public Law 845 encourages the enactment of uniform state laws for water pollution control. Based upon the review of state laws and a set of guiding principles, the Public Health Service drafted a suggested law with alternate sections to insure flexibility. In August, 1949, more than 800 copies of this draft were distributed to influential individuals and groups throughout the nation. Upon receipt of their comments, seven outstanding state officials were asked to advise on the final draft. The final adjusted document has been submitted to the Council of State Governments (endorsed and recommended to the states for favorable consideration by the Council of State Governments, October 19, 1950).

There has been much discussion about the need for uniform state legislation in this field. The underlying concept and purpose of uniform legislation is to facilitate interstate cooperation for a more concerted attack on water pollution. While uniform legislation need not mean identical legislation, many benefits would be derived if the states adopted legislation uniform in basic principles. It is not expected that the states will throw out their existing legislation and adopt this model law. The process of obtaining uniformity is one of evolution. States should take a realistic look at their basic statutes in the field of water pollution control and compare them with the suggested uniform law. Those familiar with state law in this field will find little that is new or radical in the suggested draft. Basically, what has been done has been to distill out the best practice from existing state statutes and, using this as a framework, develop a statute that should aid and strengthen the state programs.

Uniform state legislation should help reduce industrial pollution. The significant response that industry is already making to the public demand for prevention and abatement of pollution should not be overlooked. But in all fairness, those in industry who are leading the way, and those who follow, ought not be confronted by an array of excessively dissimilar requirements, state by state. Variations in pollution abatement requirements can be extremely important to some industries in highly competitive fields. From the states' viewpoint, uniform legislation should aid in reducing or eliminating bargaining between industry and states. Uniformity of statutory requirements will be an important step toward providing industry with the best possible assurance of what is or will be required over a reasonable time period.

State Organization for Pollution Abatement

The lack in state water pollution control agencies of adequate representation for the principal interests concerned with pollution abatement has been a drawback to more rapid progress. In recent years there has been a definite trend to organize pollution control so that all major interests have an opportunity to express their views. To date, 24 states have taken such action.

It is imperative that state agencies continue to see pollution abatement as a matter which goes beyond the direct implications to public health. Recreation, water sports, fishing, propagation of other aquatic life, agriculture, and industry have fundamental interests in pollution control which should be recognized fully. These interests must be reflected in accepted policy. If the "old line" state agencies historically responsible for controlling pollution do not give adequate consideration to all allied interests in water resources, they will be superseded, even though they may have the principal competence in the field. The trend toward general conservation of natural resources, the specific impetus being given river basin development programs, and the continual and increasing demands upon

water resources, are unmistakable signs. States should look to the future, read the signs, and adjust accordingly.

Intergovernmental Cooperation

For purposes of developing comprehensive programs, the Public Health Service, jointly with the states, subdivided the country into approximately 260 watershed areas. About half of these areas are interstate in nature. The existence of these interstate basins determined in a substantial degree the necessity of federal government participation in pollution control.

Compacts and agreements have been entered into between states with congressional consent since the earliest days of the nation. However, the use of this device during the early period was on a very limited and restricted basis. The Colorado River and New York Port Authority compacts initiated a new era in the use of interstate compacts. Both resulted from the growing need for joint state administration of problems local in character but beyond the jurisdictional reach of any one state. These were problems that reflected the growth of the country and the intensification of the processes of production, transportation and communication. During the 1920's the compact began to be viewed more widely as a possible means of strengthening states and integrating their administration.

In the field of water pollution control, 10 interstate compacts have been developed. They provide the approach to effective interstate cooperation. Except for the Interstate Sanitation Commission and the Ohio River Valley Water Sanitation Commission, powers of the interstate agencies have been principally planning and advisory. However, these two have been provided with regulatory powers as well. More recently, the Bi-State Development Commission, a compact between Missouri and Illinois for the St. Louis-East St. Louis area, has shown how this device can be used for direct operational control over a limited regional area. Here, the Commission can construct and operate as well as plan and enforce.

The policy of the federal government in the further utilization of compacts is contained in Section 2(b) of the Water Pollution Control Act, which directs the Public Health Service to "encourage the formation of interstate compacts." It is believed that the use of interstate compacts as a means of controlling interstate pollution should expand. Successful utilization of compacts will result in more effective application of the Water Pollution Control Act. Moreover, it will strengthen the states in their work.

What Can The Federation Do?

This Federation includes in its membership the top competence in the country in the field of water pollution control. It is reasonably objective, practices sound engineering, and has been acutely aware of the public interest. The members of the Federation, individually and collectively, through the member associations and the national Federation office, should strive to become a greater force in the democratic processes that operate around us every day. It is believed that the professional engineers, other professional components, and the trained and informed members of the Federation not only should be responsible for the technical elements of pollution abatement, but also should continually lend their strength to policy determination as well.

In terms of concrete elements of action, it is suggested that local associations learn the specific needs of the areas they cover and see that they are made known. These needs may require state legislation to provide better organization or financing for pollution control. There may be specific project needs. Perhaps comprehensive programs should be adopted or more at-

tention given to operation. Hearings at the federal, state, and local levels should be attended. With the facts in hand, members of this group can speak with logic grounded on technical competency and broad understanding. It is feared that the powers of individuals to aid in achieving action in our democratic society are often underestimated.

National Defense

All are aware of what the nation can do to improve the living standards of its citizens in peacetime. The signs indicate, however, that it may not be given to this generation to work in an environment of complete peace. Members of the Federation bear a heavy responsibility for maintaining the high standards of health that have been achieved in the nation. In addition, as the quality of the water resources diminishes, as it undoubtedly has since 1940, added responsibilities must be borne to support and safeguard the operation of the industrial machine. Industry can be reduced in capacity, prevented from expanding, or even wiped out for lack of water of sufficient volume and quality. Many know that in some river basins in this country there has been an approach to critical conditions between water quality and the uses to which the waters must be put.

It does not take a great deal of foresight to see that in many areas the surface waters of the nation will become a most precious natural resource, to be guarded and husbanded against waste and destruction. It is hoped that more positive action to save this resource will not be further delayed. Many of the needs are known; specific needs in critical areas are now being investigated. For the immediate future it is probable that pollution abatement projects should be pointed to critical areas. Economic reports indicate that unless significantly greater defense demands are made upon the nation, it may be possible to meet most of the demands for construction in this field. However, it will be wise to plan for a reevaluation of program, rather than for business as usual.

Pollution of surface streams is the resultant by-product of Twentieth Century development. At no time during this century has the upward trend in pollution been checked. Decade by decade, stream conditions have grown progressively worse. By comparison, over the past decade, including the war years, the rate of increase has been alarming. Simple mathematics will show that over wide areas stream conditions are reaching the critical stage.

As action programs for the predictable future are blueprinted, aggressive remedial measures in critical areas should be subordinated only to the most urgent national defense needs.

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CORRECTION

In the paper on "Influence of Velocity on Sulfide Generation in Sewers" (THIS JOURNAL; Sept., 1950), Eq. 8 (page 1134) should read:

$$N_{Re} = 5{,}700 \left[\frac{A}{b} (\text{B.O.D.})\, f(T) \right]^{0.89} \qquad (8)$$

THE OPERATOR'S CORNER

CONDUCTED BY HERBERT P. ORLAND

OPERATION AND CARE OF ELECTRIC MOTORS *

BY F. A. KUHL

Superintendent, Water and Light Dept., Breese, Ill.

Most operators know only too well how important it is to keep motors and control equipment from becoming overheated from internal or external sources. Also well-known are the dangers resulting from inadequate lubrication, but every operator should also clearly understand the resulting danger from over-lubrication. This is extremely important, as accumulations of oil or grease resulting from over-lubrication will rapidly injure the winding insulation of the motor. Therefore, close adherence to the manufacturers' lubrication recommendations cannot be over-emphasized.

Protection from Moisture

Although operators appreciate, in a general way, the importance of protecting motors from moisture, many do not fully appreciate what constitutes the right kind of protection. Just because an outdoor type of motor is totally enclosed, or is of the open type and located in a dry spot, does not mean that the insulation will not deteriorate because of the absorption of moisture. On the other hand, it does not mean that the winding insulation will deteriorate because a small amount of condensate accumulates in the bottom of the motor or the motor is located in a warm room in which high humidity prevails. Protection from moisture resolves itself into the problem of keeping the insulation from absorbing enough moisture to cause deterioration and thus result in the motor burning out. To avoid this condition, the motor should not only be protected from splashing or falling water, but also should be installed in a warm room or operated up to normal temperature at least once a week to dissipate any moisture or condensation which may have accumulated on the insulation. The foregoing applies to all motors, but especially to those operating at 440 volts and above.

When motors are operated only infrequently, and in addition are exposed to dampness or extreme temperature ranges from day to night, adequate protection should be provided by applying heat to the windings when the motor is not in operation. Motors operated only a few times a year should either be run at stated intervals to dry them out, or equipped with electric space heaters.

It would be still better to install a control system that will automatically supply low-voltage electricity to the motor so that a small amount of current will flow through the windings,

* Excerpts from an article in *The Digester*, 12, 2, 6 (1950).

supplying only enough current to keep the winding slightly warm, and thereby the insulation dry. This system is much more efficient than using space heaters. When space heaters are employed, extra wiring and conduit are necessary. With the low-voltage automatic control system the same wires from the starters to the motor can be used to supply low voltage to the windings when the motor is not in operation. Normally the savings in power consumption alone will compensate in a short time for the extra cost of the feature, to say nothing about doing a much better job of protecting the motor.

How to Clean

When electrical apparatus gets dirty or greasy and moisture has penetrated the insulation, it must be cleaned and dried. The methods of cleaning include wiping off the dirt with a clean dry cloth, blowing it out with air pressure, drawing it off with suction apparatus, and removing it in various ways with solvents.

On small motors, when dirt has collected on exposed parts, cleaning with a dry cloth or brush may be satisfactory. Waste should not be used, as the lint will adhere to the insulation and collect dust, moisture, and oil.

Blowing out dirt with compressed air at a pressure of about 50 lb. per sq. in. is usually the most effective, particularly when the dirt has collected in places that cannot be reached with a cloth. Generally, cleaning can be done more quickly with compressed air than with a cloth, especially on large motors. Compressed air should not be directed against the insulation until certain that it is free from moisture that may have accumulated in the air lines from condensation. Air with too much pressure should never be used, because it may loosen the binding tape and damage the insulation.

If the accumulation of dirt contains oil or grease, a solvent will usually be required to remove it. There are several types of solvents in general use for this purpose (petroleum distillates, benzine or gasoline, and carbon tetrachloride, or a mixture of the two).

Benzine or gasoline has the least corrosive action on the insulation varnishes. For that reason, where conditions permit, they are preferable to other solvents.

The commercial safety type solvents minimize the fire hazard and should be used in preference to gasoline or benzine, but ample precaution should nevertheless be used to prevent fire or explosions. When this type of solvent will not properly clean the insulation, a mixture of 50 per cent carbon tetrachloride and 50 per cent benzine, or 60 per cent carbon tetrachloride and 40 per cent gasoline may be used. This mixture is non-inflammable, but the vapors mixed with the right proportions of air are explosive. In extreme cases it may be necessary to use carbon tetrachloride straight. Although it is much more corrosive in its action than the petroleum solvents, it may be used for cleaning windings with mild risk if reasonable precautions are taken.

Solvents are generally used by wiping the insulation with cloths moistened with the cleaning fluid. In special cases, the solvents may be sprayed on the insulation or the insulated parts may be dipped into the solvents.

At this point a few words of caution are in order. When petroleum distillates are used, careful guard must be maintained against fire and explosion. Both benzine and gasoline are very inflammable; their vapors are extremely explosive when mixed with the proper proportion of air. It is imperative to provide good ventilation and keep the fire risk at a minimum. Clothing saturated with the solvent should be removed at once, or at least before leaving the job. Always have fire extinguishers handy. Keep metal tools from striking other metal objects. Workmen's shoes should not have pro-

truding nails. If using a hose to spray either cleaning solution or varnish, be sure that the nozzle is grounded. When carbon tetrachloride is used, the workmen should be guarded against breathing fumes, and should be under close observation of someone familiar with artificial respiration. Where the conditions are particularly bad, such as in pits or other closed places, gas masks should always be used. Adequate ventilation should always be provided when any type of solvent is being used.

Drying the Insulation

After cleaning it is always a good policy to check the insulation resistance. If it is found to be low, it naturally becomes necessary to dry the insulation of the windings.

There are three general methods of drying the insulation:

1. External heat.
2. Internal heat.
3. A combination of internal and external heat.

Where possible, the apparatus should be dried under vacuum while hot, an extremely effective process. The drying process should be continued until the insulation resistance has dropped to a minimum, and has then increased until at least one megohm for each 1,000 volts of operating voltage is indicated by a megger; but in no case less than one megohm, regardless of voltage.

Starters

Motor starters at sewage disposal plants may be divided into the following general types:

1. Manual starters.
2. Reduced voltage starters.
3. Resistance type starters.
4. Magnetic linestarters.

On all, the following general consideration must always be observed. Before removing the cover to inspect or adjust a starter, make sure the disconnecting switch is open and the control circuit is dead. All parts must be kept dry and clean—this is of fundamental importance. Inspection should be made at regular intervals for best results. In general, monthly inspection will be sufficient, although in particularly severe service it may be desirable to inspect more often.

Because at least 90 per cent of all starters at sewage treatment works are of the magnetic linestarter type, the following maintenance hints are confined to this type of unit:

1. Do not lubricate contact tips or bearings.
2. Magnet sealing surfaces should occasionally be wiped with an oil-moistened cloth to prevent rust and noise.
3. Check tightness of all connections, particularly connections to the overload heaters, as a loose connection here will cause local heat that will affect the calibration of the relay.
4. Make sure that the shunts are not broken or touching other parts.
5. If the contacts become excessively rough or burned in service, they should be dressed with sandpaper or a fine file (do not use emery cloth). Contact tips should be replaced when approximately two-thirds of their thickness is worn away. These are removable; generally, only a screwdriver is needed for the change.
6. Any excess deposits should be removed from the inside surface of the arc boxes adjacent to the contacts, and any broken arc boxes should be replaced.
7. See that all moving parts work freely.
8. Disconnect motor and manually test the start button, the stop button, the overload relay, and the reset.

Most linestarters are provided with overload relays, the function of which is to disconnect the motor upon sus-

tained overload. The action of the overload relays depends on the current in the motor circuit to raise the temperature of the heater element of the thermal relays. The thermal relays then open the control circuit of the starter, which in turn disconnects the motor from the power supply.

These thermal relays have the inverse time limit feature, which means that the greater the overload, the shorter the time of tripping. They provide excellent protection against overloads and momentary surges, but do not protect against short-circuit current. For protection against short circuits, either fuses not exceeding four times the motor full-load current, or time limit circuit breakers set at not more than four times the motor full-load current should be employed. Or, instantaneous-trip circuit breakers should be installed ahead of the line-starters. Where fuses are used, it is good practice to use, in addition, a disconnecting switch ahead of the fuses.

Heaters of thermal relays are made with different current ratings so that within its limits any starter can be used with different size motors and will still afford proper protection by selecting the size of heater element that corresponds to the full-load current of the motor being used. Tables showing the ampere rating of heaters can usually be found on the inside of the starter box, or can be obtained from the manufacturer. In general, the ampere rating of the heater should be aproximately 120 per cent of the motor full-load current.

Renewal Parts

Good operation and maintenance demands that a stock of renewal parts be kept on hand so that they are available when needed. This is especially true where the service is severe and where continued service is essential. It is well to have stationary and movable contacts, magnet coils, and shunts on hand. The cost of such renewal parts is very small compared to the cost of a shutdown, and will also save the inconvenience and embarrassment usually resulting from a shutdown.

PLANT OPERATION AND IMPROVEMENTS AT FREDERICK, MD. *

By R. H. Hartman

Superintendent, Sewage Treatment Plant, Frederick, Md.

Prior to 1937, Frederick, Md., with a population of 15,300, was completely without a sanitary sewer system. The disposal of wastes for each property was the problem of the property owner and varied according to his ingenuity, ambition, or prosperity. For the most part wastes were disposed of by the use of cesspools, septic tanks, and privies, the latter being the more popular. Persons owning property in the vicinity of a storm drain or along Carroll Creek had their problem of waste disposal simplified considerably, as overflows from cesspools were piped direct to the storm drains or creek. Few of the cesspools were cleaned after being built and it would not be long before sewage would be flowing directly into the creek or eventually find its way there through the storm drains. This unsanitary condition was not due to the wish of the people, as was demonstrated in 1935, when the city decided to call upon the Public Works Admin-

* Presented at 1950 Annual Meeting, Maryland-Delaware Water and Sewerage Association; Cumberland, Md.; April 27–28, 1950.

istration for a 45 per cent grant and put the sanitary sewer construction problem to the voters for a decision. The grant was obtained and the vote was in favor of the sewer construction by a 5 to 1 majority. The lack of sanitary facilities was due chiefly to lack of sufficient water supply, which was corrected in 1924 and 1931.

When it was decided to construct a sanitary sewer system, the city employed consulting engineers, who proposed, in addition, to eliminate the garbage disposal nuisance by designing a plant to dispose of the sewage and refuse combined. This proposal was readily accepted by the city as it eliminated two nuisances at one time. A site on the west bank of the Monocacy River, approximately 1¼ mi. east of the city limits, was decided upon for the location of the disposal plant. The work was gotten under way in the latter part of 1935 and completed in the fall of 1937.

It was about this time the city decided to institute its own garbage, trash, and ash collection and removed all restrictions on amount of material to be picked up from each family. This also eliminated the nuisance that existed from accumulated materials. Two 8-cu. yd. closed-body truck units were secured at that time. A 12-cu. yd. load-packer has been added since.

The disposal plant was put into operation upon completion of the sewer system in October, 1937. Sewage flows to the plant by gravity through a 36-in. line crossing Carroll Creek on the plant bridge. Entering a concrete channel, it passes through stationary course screens and a Parshall flume. A dip in the channel gives depth for prechlorination, and acts as a grit chamber. The sewage then enters the clarifiers, consisting of two rectangular concrete tanks equipped with continuous straight-line sludge mechanisms. The effluent from the clarifiers originally flowed into the west side of the Monocacy River. Space was provided for further treatment of the effluent when this becomes necessary.

The sludge flows by gravity from the clarifier hoppers, or sludge chambers, to the raw sludge well in the control building. From the raw sludge well it is pumped to two concentration tanks, located outside the building. The sludge is run by gravity into the concentrated sludge well in the control building. This well serves as the pick-up point for a bucket elevator, which raises the sludge to a concrete sludge mixing tank in the control room. As the sludge enters the sludge mixing tank it is given a dose of ferric chloride and lime for conditioning. The sludge and chemicals are mixed by compressed air and baffles in the mixing tank.

From the mixing tank the sludge is passed directly to the two filters. Each filter has an area of 100 sq. ft. Using both, a 24-hr. accumulation of sludge can be run through the plant in 4 hr. actual filter time. Dried sludge from the filters is carried by a belt conveyor to the floor of the incinerator charging room. Here the dried sludge is fed directly into the incinerator with the garbage and combustible trash. Filtrate water from the vacuum filters is pumped back to the clarifier influent channel.

The incinerator consists of two furnace chambers, two combustion chambers, one preheater, one stack, and has a daily capacity of 60 tons.

The municipal disposal plant is operated six days a week. The incineration of the garbage and trash is carried on at the same time the sludge is being conditioned and filtered.

At 4:00 A.M., fires are started in both chambers of the incinerator by using wood boxes saved from the previous day. At this time garbage and trash start arriving at the plant and a light charge is then placed on the newly started fires. When a good bed of coals is formed, a full charge of garbage and trash is then added, topped

off with a charge of about 200 lb. of filter cake. The preheater is then started and in 10 min. the incinerator temperature is up to 1200° F. The fireman then rakes the filter cake from the top of the burning charge down onto the grates, where it burns of its own accord. The charging process is now repeated each 30 min., using 8 cu. yd. of garbage and trash and 500 lb. of filter cake piled on top. After the first full charge has burned down, the incinerator temperature is up to 1600° F. For the existing conditions, operating at 1700° to 1800° F. gives good incineration. After the recuperator tubes heat up, the preheater gives a temperature averaging 350° F.

As the ashes accumulate on the grates, the charging capacity of garbage and trash is proportionately decreased, amounting to 4 cu. yd. at the end of an average day. The incinerator is operated for an average of 7½ hr. daily.

Wet weather has considerable influence on the length of time required for incineration. When the garbage and trash comes to the plant wet the whole operation is slowed down by as much as several hours. During the summer months, when the garbage and trash is heavy with corn husks and grass from lawns and it is wet from rains, it is occasionally necessary to add fuel.

The garbage and trash are separated into burnable and nonburnable collections. All burnable material is hauled to the plant and dumped on the floor of the charging room; nonburnable trash and ashes are gathered by the same collectors and hauled to the old dump that first served both purposes. In spite of all the rules and regulations in effect concerning separation of burnable from nonburnable trash, a good many cans and ashes find their way to the plant. These simply help choke up the grates and occupy space in the incinerator. Ashes are removed from the incinerator each day by the night attendant and dumped near the plant on a plot of ground acquired for that purpose.

The stationary bar screens in the concrete channel of the sewage plant are raked by hand once each hour. The rags and other coarse material removed by raking are burned in the incinerator.

The continuous sludge removers in the clarifiers are in constant use. Intermittent operation of this apparatus was tried, but gas boils rising to the surface carried large quantities of sludge with them.

Prechlorination is used ahead of the primary tank. The dosage varies with the season. In cold weather, 70 lb. are added per 24 hr.; in warm weather, 100 lb. This by no means gives sterilization, but it does reduce the gas action noticeably when drawing the raw sludge from the pits to the raw sludge chamber of the clarifiers. The chlorine further greatly reduces the odor nuisance at the plant. Residual chlorine cannot be detected in the clarifiers more than a few feet from the influent end.

Frederick sewage is mostly of a domestic nature. There are three canning factories in the city, but they only operate about six weeks out of the year. All during the war and up until December 1, 1948, the plant burned the garbage and treated the sewage from Camp Detrick.

Realizing the need for more treatment, due to the increase in population from 15,000 in 1937 to 20,000 in 1947, a consulting engineer was requested to make a survey of the needs and improvements at the city disposal plant. In March, 1947, the following needs and proposed improvements were submitted:

1. One 120-ft. diameter high-rate trickling filter with a side stone bed depth of 4 ft. The stone bed will contain approximately 1,850 cu. yd. of stone varying in size from 2 to 4 in.

This bed is designed for 3,600 lb. of raw B.O.D., based on a population of 21,000 persons. At a B.O.D. of 0.17 lb. per person, or 3 m.g.d. of sewage at a raw B.O.D. of 145 p.p.m., a rotary distributor would apply the sewage uniformly and continuously over this stone bed. The sewage will trickle through the stone bed and be discharged by gravity to a final settling tank.

2. One final settling tank 100-ft. diameter with 9½-ft. side water depth. This tank will be designed for a sewage flow of 3 m.g.d. with recirculation of another 3 m.g.d. at a 2½-hr. detention with a combined flow. The tank will be equipped with rotating mechanism to collect the sludge for flow by gravity back to the inlet side of the existing primary settling tank.

3. One low-lift sewage pumping station to be built between the present out-flow pipe and the secondary settling tank and equipped with a diversion chamber on the out-flow pipe, with a connection to the secondary settling tank for recirculation. Four mix-flow 2,500 g.p.m. propellor-type pumps, with 15 h.p. motors.

4. A sludge thickener in one of the existing sludge holding tanks. This work was started August 2, 1948, finished and put in operation May 13, 1949. This additional treatment and improvements have proven money well spent. The records show it has decreased the solids in the final effluent practically to zero. It has also reduced the B.O.D. about 80 per cent. The sewage flow averages 2.7 m.g.d., and concentrated sludge from the primary tanks averages 950 cu. ft. per day.

Sludge cake burned daily at 70 per cent moisture	5 tons
Garbage and trash burned daily	16 tons
Average tons burned daily	21 tons

There is another contract to be let out in the near future for:

1. A mechanical bar screen in place of the manually cleaned screen.

2. A duplex sludge pump installed alongside the present sludge pump, with automatic controls.

3. At present, the plant effluent is discharged along the west bank of the Monocacy River. This new contract will call for an under-water pipe laid several feet under the bottom of the stream, with four outlets directed downstream. This method of dispersing the sewage in the stream will give it a better chance for dilution.

The city of Frederick has spent approximately $1,000,000 on water and sewage projects during the period 1948–50.

THE DAILY LOG

Kenosha, Wisconsin

By Harold T. Rudgal, *Superintendent*

January 1—Air temperature at 10° F., which is just too cold for comfort. Because of the holiday, only a skeleton crew is on duty—one man per shift. Plant heating system temperatures; leaving boiler 160° F., into digesters 135° F. Automatic temperature controller on digester heat system working O.K.

January 2—Started work on both the December and annual reports. Looks like an overwhelming job just at its beginning, but it certainly pays off when completed.

January 4—Regular Friday greasing and oiling program and checking of all alarms showed all O.K. Careful attention to this routine detail has saved

considerable grief and headaches since its establishment. Sewage flow above normal, due to melting ice and snow in the thawing temperatures now prevailing.

January 5—Plant taking only part of the city's total sewage flow; old man "Sun" doing his stuff. All storm overflow points checked and found to be bypassing excess flow full blast. The 10-m.g.d. electric motor driven stand-by pump was placed in service to give this unit a work out. Plant flow then increased to 23 m.g.d. with two pumps in operation.

January 7—Started dismantling No. 3 sewage pump gas engine for annual inspection and overhaul. Appears to be less carbon than in previous years.

January 8—Engine heads taken to city garage for insertion of new sleeves and reseating of complete new set of valves. Furnished digested sludge data to a local fertilizer manufacture, who is showing more and more interest in the plant's end product.

January 9—No. 1 clarifier cross flight drive chain jumped its sprocket due to icing condition. By placing the 450-g.p.m. portable pump into operation to pump from clarifier No. 1 to No. 2, the water level down enough by 2 P.M. to make repairs. Clarifiers back in normal operation at 3:15 P.M. As a corollary preventive measure against recurrence the idlers on all flight drive chains were tightened.

January 10—Operating results poor: only 40 per cent reduction in suspended solids. The greatly diluted and above-normal thaw flow is apparently causing the difficulty.

January 11—Finished reassembly of No. 3 engine, although a warped casting occasioned trouble in connecting the exhaust manifold. Finally got the engine running; a leak was found in the gas fuel regulator.

January 14—No. 3 sewage pump placed back in service. The overhauled gas engine drive unit is purring along nicely. Checked interceptor sewer inlets; all O.K.

January 15—"Oscar," the gold fish, plant mascot since his rescue from the comminutor chamber, is with us no longer. Sometime during the first shift he either got too frisky or his worries became too great to bear. He was found dead on the laboratory floor after having flipped himself out of his 2-liter beaker home.

January 16—No. 2 sewage pump gas engine being torn down for annual checkup and repairs. New piston rings will have to be installed this time.

January 17—A sludge survey of the clarifiers shows that all clarifiers contain sludge in storage.

Pumped 50,000 gal. of bottom sludge from No. 1 digester to drying bed No. 6. In working to correct a sludge pump stoppage, the boys forgot to relieve the pressure in the discharge line. As a result, when loosening the cap over the ball check chamber, the operators got a sludge bath and made a general mess of the control room. They know better, but every once in a while they forget or get in too much of a hurry.

January 19—Drained 55,000 gal. of apparently normal supernatant from the No. 2 digester to the clarifiers Engine overhaul proceeding on a satisfactory schedule, with all units getting new spark plug cables with removable terminals.

Cleaned the ice from equipment drive sprockets. This phase of maintenance is getting more attention since the trouble with the chain jumping off the sprocket.

January 22—A local industry called the plant yesterday to give notice that a vat of iron pickling waste would be discharged to the sewers starting at 7 A. M. The pickling liquor reached the plant, as a slug, at 10:10 A.M. If the waste discharged was started as per schedule, sewage from the north end of the town reaches the plant in a little over 3 hr. This information

should prove useful in planning for future handling of waste discharges from that area.

Placed 100 lb. of rock salt around the rims of both digester floating covers to prevent their getting "hung up" by ice. Air temperature down to 2° F.

January 24—A thorough inspection of the plant was made to check on housekeeping. The only criticism—dust on top of boilers. The rest of the plant is in tip-top shape. It's very gratifying that the operators take pride in the appearance of the place in which they work. The sewage plant still rates high as one of the cleanest and best maintained places in town.

Quite a number of small fish were noticed in the sewage flow reaching the plant. A check of the sewer overflow dams shows no backflow from the lake. Probably the fish are from Simmons Co. cooling-water discharge, as this plant uses untreated Lake Michigan water for cooling purposes.

January 27—Pumped sludge from No. 1 digester to bed No. 8: sludge temperature 78°; 10.2 per cent solids and 41 per cent volatile matter. All alarms were found to be working O.K. on the weekly checkup and greasing schedule. The gas flame of the No. 2 heating boiler is getting an orange tinge, which indicates that the boiler flues are plugging up. Switched to No. 1 boiler and scheduled No. 2 for cleaning tomorrow.

January 28—The floating cover on the No. 1 digester tipped 15 in. After closing the gas line from the digester, the cover was leveled by opening the center hatch and wasting gas to the atmosphere. A little sleuthing showed the floating cover relief valve frozen—it was finally thawed out by pouring warm oil into the relief valve well. A later check showed the oil level holding constant, so the cast-iron reservoir well was not cracked. More frequent checks will be necessary to prevent this happening again.

January 30—Assembled the hanging wood platform on the 5-ton crane in the pump room, in preparation for the annual washing of the plastered ceiling. A detailed check of the platform assembly shows the wood to be still in good shape. One can't be to careful, as the men will be working 30 ft. above the lower pump room level.

February 1—The pump room ceiling wash job was completed today. The men did a fine piece of work, but it looks as if a new paint job will be necessary next year. The laboratory worked on determining the amount and effects of copper in the sludge; results were about normal.

February 4—Checked the sludge pump discharge rate by stop watch, timing the emptying of the sludge sampling box. This method is believed to be more reliable than a check on pumping rate by use of a V-notch weir in the sludge collection chamber. The pumping rate turned out to be 60 to 62 g.p.m. One of the city councilmen visited the plant for the first time. He appeared to be favorably impressed and expressed greatest surprise about the use of sludge gas as fuel for operating the gas engine driven pumps. He also was very complimentary about the plant housekeeping; we were pleased to give the credit to the operators, who carry out the daily cleaning schedule.

February 11—Just about finished with the annual schedule of washing all glazed tile walls and plastered walls and ceilings. Started white-cement-and-lime paint job of pipe gallery walls and ceiling. Concrete surfaces are thoroughly wet down and then white cement coating applied while the surfaces are damp.

February 12—Flushed the clarifier inlet channels by routing the entire plant flow into each one of the four clarifiers; 10 min. time for each. Also, reduced the sludge pumping time for clarifier sludge hoppers No. 3 and 4, as a sludge survey shows less sludge in storage in these clarifiers.

Found the Washington Park creek crossing overflow plugged. After much work, a small wine barrel was broken up and the pieces dragged out. This is a new item added to the list of sundry things found in the sewers and at the plant.

February 14—St. Valentine's Day, but events at the plant were anything but rosey or lovely. There was an electrical power outage of 3½-hr. duration, the longest experienced to date, when the power line burned out, in trees, about four blocks from the plant. The only equipment able to be operated was the gas engine driven sewage pump and the stand-by gas engine driven heat system circulating pump. All comminutor gates were opened and the units operated as non-revolving screens. When the power came back on, all equipment and electrical switches and controls were checked. This seemingly routine necessity after a power outage could be a source of much subsequent trouble if overlooked.

February 15—The city is hauling dried sludge to the former city dump at the lake front. The sludge is to be mixed with soil to form top surfacing of what will be new park area; the water department's crane is being used to load the trucks.

February 16—An awareness of the unseen municipal utility was impressed on the president of the City Council, who today visited the plant for his first tour of the works. Another important and welcome visitor was an insurance inspector, who surveyed the plant in connection with a workman's compensation insurance proposal to cover all city employes.

February 21—Steady rain all day. Because of the heavy flow, the 42-in. hydraulic influent control sluice gate was closed to 0.4-ft. opening; plant flow is at a 20-m.g.d. rate, with the balance of the storm flow being bypassed to the lake through the overflow stations. Raw sewage temperature of 38° is the coldest of the year, although the raw sludge temperature only dropped to 50°.

February 22—Washington's Birthday—but at least he didn't have these worries. The No. 2 sewage pump stopped operating at 4:47 P.M. due to overheating of the engine. However, the trouble was noticed before the wet well level reached the height necessary to place No. 1 electrically driven stand-by pump automatically into service. This experience proves the worth of checking the stand-by pump operation every two hours to make sure the pump is primed and goes into action upon tripping of the float control switch. Overheating of engine was traced to too little heat system circulating water being routed to the engine heat exchangers; increasing the water circulation to the engines corrected the situation.

EMERGENCY STREAM SAMPLER

By C. Edward Fuess

Superintendent, Sewage Treatment Plant, Sturgis, Mich.

When a stream sampler was urgently needed several years ago and supplies were scarce, one was made from two 2-qt. wide-mouth Mason fruit jars and a few pieces of steel.

The frame consists of a ½-in. thick steel plate 5 in. wide and 10 in. long, to the center of which is welded a ½-in. diameter steel rod 10 in. long (Figure 1). An eyebolt welded to the top of the rod serves for attaching a chain or rope. Two 2-qt. wide-mouth Mason fruit jars are fastened to the frame by means of thin steel straps

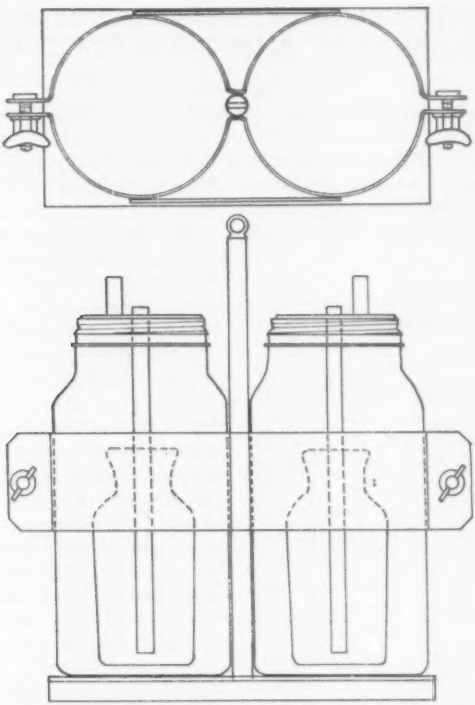

FIGURE 1.—Assembly of emergency stream sampler from scrap metal and 2-qt. Mason jars.

shaped to fit the jars and fastened to the center rod. The jars are held firmly in place with bolts and wing nuts.

Kerr two-piece Mason caps are used on the jars. These metal covers have their own sealing bands and assure a quick and easy seal for the jars. Each cover is drilled for two $\frac{5}{16}$-in. copper tubes. The center (inlet) tube extends $8\frac{1}{4}$ in. into the jar; the vent tube is flush on the inside and extends about 2 in. above the cover.

A sheet of $\frac{1}{8}$ in. gasket rubber between the jars and the steel plate prevents accidental breakage of the glass jars. Each jar will accommodate one 300-ml. B.O.D. bottle and allow approximately 5-time displacement of the B.O.D. bottle volume.

The sampler has been in use for more than three years and has proven satisfactory in all respects—low cost, ease of handling, clean, and easy sealing of the cover.

SEWAGE CHLORINATION, EMERGENCY B.O.D. REDUCTION, AND ODOR CONTROL *

By A. J. Gully

Graduate Assistant, Chemical Engineering, Louisana State University, Baton Rouge, Louisiana

Chlorination is probably the most versatile tool used in the treatment of sewage. Sewage treatment may be approximately divided into three processes:

1. Primary treatment.
2. Secondary treatment.
3. Disinfection.

Chlorine is used to a considerable extent in all three.

In the field of disinfection, chlorination stands alone as the principal treatment. The application of chlorine in the first two processes is usually for the purpose of solving troubles arising from the other two treatment methods, or as aids in their operation. Some of the benefits to be derived from chlorination in connection with primary and secondary processes are odor control, psychoda fly control, B.O.D. reduction, and improved control of sludge bulking in the activated sludge process. This is not a complete list of the functions of chlorination as adjuncts to the other methods. Almost invariably when chlorination has been used with the idea of solving one particular problem, other important benefits have been realized.

Before going into the chlorination treatment, it is well to define two terms, "chlorine demand" and "residual chlorine," which are widely used in connection with chlorination. When chlorine is added to sewage, it reacts with many substances, each of which consumes a part of it in reaction. Chlorine demand is the amount of chlorine required to satisfy the demand of all these substances in the sewage and still have 0.1 p.p.m. of unreacted chlorine at the end of a 10-min. contact time. Any chlorine added over and above the amount required for the chlorine demand of the sewage is called "residual chlorine." These terms are very important in determining the dosage of chlorine necessary to achieve a particular purpose.

For complete disinfection, it has been found that a slight chlorine residual must be present after a given contact period. The exact residual required is dependent upon local health department requirement, but if a residual of 0.5 p.p.m. is present after a contact period of 15 min., one may be reasonably sure that completed disinfection has been accomplished. On the average, the amount of chlorine required for raw sewage disinfection varies from 10 to 20 p.p.m. For disinfection of secondary treatment effluents, the requirements are lower, varying from 6 to 12 p.p.m. for trickling filters, 3 to 6 p.p.m. for sand filters, and 2 to 4 p.p.m. for activated sludge effluents.

Bacteria are not killed instantly upon contact with chlorine, but a contact period of 10 minutes or longer must be provided for complete disinfection. If primary treatment is the only treatment process at the plant, the proper detention period for disinfection may be achieved by prechlorination ahead of the settling basin or postchlorination of the settling basin effluent ahead of a long outfall sewer. The former point of application is most prevalent.

When secondary treatment is also used, chlorine for disinfection may be applied ahead of the final settling basin, ahead of a chlorine contact

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chamber, or ahead of a long outfall sewer.

Odor Control

Raw, fresh sewage does not ordinarily emit objectionable odors, but biological decomposition of the sewage gives reaction products which are foul and objectionable. The principal odorous product is hydrogen sulfide, formed in the decomposition of sulfates and other sulfur-bearing compounds in the sewage. Sulfate splitting bacteria act upon stagnant or slow-moving sewage to produce the objectionable hydrogen sulfide in sewer gases.

Control of odors may be accomplished in two ways: (1) prevention of the formation of hydrogen sulfide, and (2) destruction of hydrogen sulfide after it has been formed. Prevention of odors is much more economical than treatment of odors already formed. It has been found that destruction requires as much as ten times as much chlorine as prevention. The reasons for this are obvious upon examination of the mechanisms of the two methods. Chlorine acts upon fresh sewage, killing or inhibiting the growth of bacteria which cause the hydrogen sulfide formation. In order to control the sulfate splitting bacteria, it is necessary to satisfy only about 25 per cent of the chlorine demand of the sewage. After decomposition has begun and hydrogen sulfide has been formed, from 50 to 75 per cent of the chlorine demand must be satisfied to control odors. Hydrogen sulfide, being a reducing agent, exerts a chlorine demand itself and its formation increases the total chlorine demand of the sewage. Chlorine reacts with hydrogen sulfide to produce hydrochloric acid and free sulfur. From a stoichiometric balance of the reactants, it is seen that 2.1 p.p.m. of chlorine are theoretically required to react with 1 p.p.m. of hydrogen sulfide. Actually to completely destroy the hydrogen sulfide, from 5 to 15 p.p.m. of chlorine are required per p.p.m. of hydrogen sulfide.

Obviously, it is advantageous to control odors by the prevention of the formation of odorous gases. The rate of hydrogen sulfide formation is dependent upon a number of factors. Large amounts of sulfur-bearing compounds in the sewage, stagnant areas and slimes in the sewers, high temperature, low rates of flow, and long sewer lines favor its formation. There may be certain times of the year or day that odors occur, whereas at other times, such as cold months or periods of high rainfall, none is evident.

If the sewage as it arrives at the plant is not objectionably odorous, chlorination at the plant just before the grit chamber or settling basin is satisfactory for odor prevention. However, if the sewage emits objectionable odors as it comes out of the water, chlorination should be applied at some point above the treatment plant. The advantages of upstream chlorination should not be overlooked. It prevents sulfuric acid formation from hydrogen sulfide, which causes sewer deterioration. It prevents disintegration of mortar and concrete joints and reduces the amount of chlorine required for odor control. The point of application should be in the sewer main far enough upstream from the sewage plant that the sewage is fresh and free from hydrogen sulfide.

Whether chlorination is applied at the plant or in the sewers, the settling tanks are maintained in a fresher condition, odors are reduced or eliminated, effective chlorine contact time is maintained, and final disinfection simplified.

B.O.D. Control

During the hot weather of summer months the B.O.D. may be excessive, overloading the treatment plant. The volume of flow in receiving streams may be so low that proper dilution of

the sewage plant effluent cannot be obtained. This being the case, further aerobic bacteriological purification takes place in the stream depleting the oxygen supply of the stream. If the oxygen supply is greatly depleted, fish will die.

Chlorination of the sewage reduces the B.O.D. load or pollution contributed to the receiving stream. Chlorine reacts with organic material in the sewage forming chloro compounds which are unfit for bacteria food. These compounds appear to be somewhat toxic to bacteria and do not exert an oxygen demand. They may be very slowly made available as bacteria food but the length of time required is such that the stream has ample time for reaeration before the oxygen demand is exerted upon it by the chloro compounds. At any rate, the rapid depletion of oxygen in the vicinity where the sewage entered the stream is reduced.

Chlorination to the point at which the chlorine demand is satisfied reduces the B.O.D. of the effluent from 20 to 35 per cent. Up to this point, the B.O.D. reduction is approximately proportional to the quantity of chlorine absorbed by the sewage. Roughly 2.4 p.p.m. of 5-day B.O.D. reduction results from each p.p.m. of chlorine added. Chlorination in plants where only primary treatment is employed is particularly advantageous. The usual 30 per cent B.O.D. reduction may be increased to as much as 50 per cent when the effluent is chlorinated.

Chlorination for B.O.D. reduction with plants using secondary treatment is usually applied to the effluent from the secondary process. However, excellent results have been obtained by chlorinating before the trickling filter or activated sludge process. Prechlorination reduces the load resulting in such marked improvement in filter performance that a lower ultimate B.O.D. is often obtained than is possible by postchlorination of the effluent.

It is sometimes advisable to divide the dosage of chlorine into two parts, one being applied to the settling basin influent and the other to the final effluent. This is known as split chlorination.

Chlorinators

For nearly all the chlorination uses, liquid chlorine is the cheapest form of chlorine produced. However, hypochloride of lime (a powder containing about 30 per cent chlorine) or high-test hypo (containing about 65 per cent chlorine) is sometimes used. The more expensive equipment required for liquid chlorine application may not be feasible for emergency dosage in small plants.

Where liquid chlorine is used, the chemical is fed by a chlorinator which takes the chlorine from a cylinder, meters it, and delivers a definite amount to the sewage. There are two different types of chlorinators available today. Most of them operate under vacuum reducing the danger of leaks but there are also semi-vacuum and non-vacuum feeders.

Three methods of control are available for chlorinator installations in sewage treatment. These are:

1. Manual
2. Automatic
3. Program

The choice of methods depends upon a balance between the degree of accuracy required, the capital investment needed, and the cost of operation.

Manual control is applicable where the total usage is small or where the load factor remains essentially constant for long periods. The chlorine rate is set by the operator and remains fixed until changed by him.

In automatic control, the chlorine rate is proportional to the volume of sewage flowing but not necessarily to the strength of the sewage. It is ap-

plicable to large installations where demand change is not great.

In some instances, the combined effect of a varied flow and varied strength produces a chlorine demand that can best be handled by a step-by-step dosage. This is applicable to plants in which the load varies during the day but is essentially the same at any given hour every day. A program may be automatically applied for periodic dosage changes.

Chlorinator manufacturer's representatives are glad to give assistance in the selection and operation of chlorinating equipment.

Chlorine is a valuable tool in sewage treatment if used properly, but if improperly used, it is ineffective or worse than nothing. Sewage treatment plants are workshops for bacteria. If chlorine is indiscriminately used, the bacteria which do regular sewage treatment work will be killed, resulting in poor plant performance.

Important points to be remembered are:

1. Chlorine is the most effective chemical used in disinfection.
2. Chlorination serves to assist in adapting a variable load to a fixed capacity plant.
3. The amount of chlorine to be applied depends upon the sewage load and the desired objective.
4. The proper point of application depends upon individual plant conditions.

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TIPS AND QUIPS

"Mothballs" for Idle Engines

Methods developed for protection of military vehicles in storage have been adapted for other gasoline or diesel driven equipment in intermittent use. By the fully proven lay-up procedures, life is lengthened, operation improved, and cleanliness of internal parts guarded. In addition, the necessity of overhaul to correct rusting and corrosion by temporary lay-up is eliminated.

The protective lay-away is made possible by special oils created for military use in the past 10 years, but now commercially available. Application is simple and requires no special equipment. Directions for best results with gasoline and diesel engines are as follows:

Gasoline engines.—Drain the crankcase when warm, fill to normal operating level with the protective oil, and run the engine 20 to 30 min. at ⅓ to ½ normal operating speed. To protect the cylinder walls, piston rings, and valves, shut off the ignition and spray 2 oz. of the oil into each cylinder through the spark plug hole while rotating the engine by hand or by the starter (at least five complete revolutions of the crankshaft). Apply the oil to the metal parts of the spark plugs, including the points and threads.

Diesel engines.—Follow the same procedure for crankcase as with gasoline engines. Remove the fuel injectors, where possible, and spray at least 2 oz. of no-rust oil into each cylinder to

protect the piston heads and valves. Rotate the engine as recommended for gasoline engines. Apply the oil to the threads and bodies of injectors.

Fuel system of all engines.—Remove as much fuel as possible from the tank and run the engine without load until it stops for lack of fuel. No fuel should be left in the fuel system during storage. Spray the inside of the tank and the filler cap threads with protective oil. In addition, thoroughly lubricate the engine accessories. Completely drain the cooling system.

The new no-rust oils meet U. S. Army requirements, including the ability to protect against high humidity and moisture condensation, to neutralize acidic products of combustion, and to be a satisfactory lubricant for spark ignition and diesel internal combustion engines. In addition, these oils must have no harmful effect on metals used in engine construction. As the no-rust oils are formulated to serve for a considerable time in the place of regular lubricants, the engine may be run on the no-rust oil without drainage when it is taken out of storage, until convenient to change. Protective oils should also be applied to exposed engine metal, such as water pump shafts or places where paint has cracked off, to provide an anti-rust coating.

New Sprocket Rim Folder

A new adjustable sprocket rim device with chain guide is claimed to be easily and securely attached to overhead or inaccessible valve handwheels in a few minutes. A specially designed chain in the desired length fits over the individual sprockets of the rim while a guide arm keeps the chain even and prevents it from slipping off the sprocket rim. Positive, trouble-free valve control is thus always available.

In addition to making existent valves accessible, the device permits placing of new valve installations wherever they should be for convenience or economy, in any high-up or out-of-the-way location, and without necessitating special galleries, runways, or catwalks. It comes in a range of 10 adjustable sizes to take care of all valve makes and types; and fits valve-wheel diameters from 2 to 30 in.

A new folder containing information on the device is available from the Babbitt Steam Specialty Company, New Bedford, Mass.

First Garbage-Free City

Lakewood Park, a new 3,500-acre suburban development southeast of the main city of Los Angeles, Calif., is attracting attention in many ways. Not only is this new community claimed to be the largest individual housing development in the world (17,000 families, or 70,000 persons), but also the entire program is expected to be completed in an elapsed time of three years at the 100-homes-per-day completion rate now in progress.

Of perhaps more interest to sewage treatment personnel, however, is the announcement that the new community will be known as "the first garbage-free city in the world." Every house is being equipped with a garbage disposal unit, thus eliminating the need for an expensive system of weekly garbage collections.

Although Lakewood Park is planned as a completely self-sufficient city in itself, with new schools, churches, parks, playgrounds, recreational facilities, and a large shopping center with adequate parking facilities, it is noteworthy that in the article at hand no mention is made of what will happen to the 70,000-population garbage and sewage load created. We can only assume that this has been relegated as an "unimportant detail" to some poor sewage plant operator, for whom it may prove a major headache!

Artificial Topsoil for New York City Parks

Reclamation of 2,135 acres of park and playground space in heretofore unusable areas of New York City, together with plans for reclaiming an additional 1,900 acres, poses for New York City's Parks Department the problem of finding topsoil to cover the new land, as well as money to pay for it. In a recent report, however, Parks Commissioner Robert Moses suggests the use of an "artificial" topsoil composed of sewage sludge, clay, and earth.

On the basis of the additional 1,900 acres of park land, it is estimated that conventional topsoil would cost $8,550,000, whereas the artificial product on the seven areas would cost only $2,784,000. The fills are formed by using low-lying ground for sanitary landfills and as spoil areas for waterway dredging.

Sludge Volume Index by Centrifuge

Operators of small activated sludge plants with limited laboratory equipment may find of considerable value the determination of sludge volume index by centrifuge. In a report (*The Digester*, 22, 2, 15) W. Grubb, superintendent of the sewage treatment plant at the Dwight (Ill.) State Reformatory for Women, mentions use of a hand-operated centrifuge for the determination. Commenting on the method, he says:

"Although admittedly a very rough check compared to sludge volume index by weight, this method is believed to be uniform enough to be of considerable value to the small plant with limited laboratory equipment.

"A recent survey of the plant has shown no factor of safety, combined with very rapid index changes. We are constantly on the verge of trouble. However, the sludge volume index has helped to avoid trouble and has enabled determination of the index at which the plant gives the desired results.

"It has been noted that the higher indices give excellent clarity of final effluent, but the sludge blanket tends to rise during surges of laundry waste, which arrive in large quantities of a few minutes duration. A lower index keeps the sludge blanket down, but at the expense of clarity. In either case, good methylene blue stability is obtained. Therefore, operation is at the higher indices, as a sparkling clear effluent creates a better impression on visitors.

"Naturally, there is some bulking, but the plant seems to have the capacity for a quick comeback. As a result of the rapid response to corrective measures, it is possible to operate with the higher indices, which give the desired result.

"The very limited equipment and the short time needed for this method of determining the sludge volume index have proven its value for the small plant."

Booklet on Porous Filtration and Diffusion Media

A new 56-page booklet containing a valuable reference aggregation of design and operation data on porous media for filtration and diffusion is now available. Sections of the booklet deal with general data on porous media of fused crystalline type, application in liquid and gaseous filtration, application in diffusion installations, and specifications for various filter and diffuser requirements.

Copies of the booklet may be obtained from Refractories Division, The Carborundum Company, Perth Amboy, N. J.

Mechanical Artificial Respiration

"An automatic breathing instrument," in the form of a portable apparatus to be used for victims of drowning, electric shock, or any kind of asphyxiation, was shown at the recent National Safety Congress in Chicago by the Mine Safety Appliances Company, Pittsburgh, Pa. The device, claimed to be the first all-purpose ap-

paratus that can be used on cases of arrested breathing from any cause, whether accidental or medical, is an outgrowth of a war-born instrument to sustain breathing of injured airmen at high altitudes.

Called the "Pneolator," it consists of a rubber and plastic facepiece connected to two valves by two 4-ft. lengths of corrugated rubber tubing. One valve administers oxygen with positive pressure at regular intervals, cycling automatically. The other valve lets oxygen flow only when the patient inhales and stops the flow on exhalation. The valves are arranged so they interchange automatically, depending on whether or not the victim is breathing. Air is not sucked from the lungs, because this action could be harmful in some cases. Instead, exhalation is by natural recoil of the diaphragm and chest muscles.

Manual artificial respiration should be applied immediately on victims of asphyxiation. When the new apparatus arrives on the scene, however, it will perform artificial respiration automatically and more efficiently than by the manual method. Unlike other devices used for artificial respiration, the pressure of oxygen administered by the cycling valve can be varied to meet a wide range of conditions, depending on the age and physical characteristics of the victim (from newly born infants with extremely delicate lungs to the most robust of adults).

According to its developers, the instrument can be operated by anyone with first aid training after a short instruction course. Packed in a carrying case containing a 22-cu. ft. tank of oxygen, enough for about one-half hour's use, the entire assembly weighs approximately 41 lb.

Start 'Em Young

One expects to find grayed and graying heads—even a few hairless ones—at the Federation's Annual Dinner, but imagine our astonishment at seeing a six-year-old at the next table in Washington! Curiosity getting the upper hand, we went over and spoke to the lad, who turned out to be James M. Brown, Jr., of Emerson, N. J., who had accompanied his mother and sanitary engineer dad (Lederle Laboratories at Pearl River, N. Y.) to the meeting.

Within a few minutes, however, even this six-year-old had become virtually a gray-beard, as a high chair was brought in for Gordon D. Arnold, Jr., of Los Angeles. His age—13 months. Perhaps the manufacturer sponsoring the Eager Beaver Society at the meeting could establish a junior auxiliary!

PLAN NEEDS! ORDER EARLY!

The present situation on critical materials will justify extra thought and planning for equipment repair and replacement, as well as for new and extension construction. An inventory of all anticipated needs, with a schedule of their order of importance, is certainly a "must" at this time.

In placing orders for materials and equipment it must be recognized that immediate delivery cannot be anticipated; the same kind of delays as were experienced during the last national emergency must be expected. At the moment, priorities are applicable only to defense orders. However, that situation may be changed overnight.

In recognition of the seriousness of any blanket restrictions on materials, the Federation is presently active in making suitable contacts at the federal level to maintain the availability of the supplies and equipment needed for construction, operation, and maintenance in the wastes disposal field.

Federation Affairs

TWENTY-THIRD ANNUAL MEETING IS OUTSTANDING SUCCESS

Reflecting the increased membership interest trend of Federation meetings in the past few years, the 23rd Annual Meeting, held at the Hotel Statler, Washington, D. C., October 9–12, 1950, set new records in both total registrations and number of men registered. Of the 904 registered for the meeting, 753 were men. The previous high total and men's attendance had been established at the Boston meeting in 1949 with 821 and 679, respectively. Ladies attending the meeting numbered 151, also bettering the second high figure of 145 set at the 1949 meeting.

The large numerical and percentage attendance of industrial waste treatment personnel shows a healthy emphasis on the problems of this field and reflects the increasing attention being accorded them by the Federation.

Representation at the Washington meeting was geographically well distributed, with every section of the United States and Canada represented, as well as visitors from England, France, Netherlands, Germany, Turkey, Norway, Italy, Greece, and Japan.

To the co-hosts for the meeting—the Maryland-Delaware Water and Sewerage Association and the Federal Sewage Research Association—the Convention Management Committee, and the Local Arrangements Committee, headed by Ralph E. Fuhrman, great credit is due for the careful and efficient planning and management of the meeting. The smoothness and precision of presentation of the various convention events resulted from diligent and painstaking attention to detail by the various local committees.

The 23rd Annual Meeting was convened at 10:30 A.M. on Monday, October 9, 1950, by President A. H. Niles. After reviewing the highlights of the Federation's 1950 activities, President Niles commented briefly on planned activities for the coming year. The business portion of the opening session was concluded with the Executive-Secretary-Editor's report by W. H. Wisely, following which Brigadier General Gordon R. Young, Engineer Commissioner for the District of Columbia, welcomed the Federation and its delegates to Washington.

Technical Program

The technical program developed by the Program Committee, under the chairmanship of F. W. Gilcreas, was top-notch in quality and diversity of speakers and subject matter, in keeping with the excellent standards of preceding Federation meetings. In addition to topics of broad interest to all Federation members, there were many papers on specific pollution and waste treatment problems. The Industrial Wastes Forum, developed around topics of interest to industrial representatives and now in its third year, was extremely well attended by that group. In fact, attendance at this session was greater numerically than that at the concurrent and always popular Operators' Forum. The spirited discussions from the floor in both forums were indicative of the great interest aroused by the topics chosen.

The technical program presented at

Washington was exactly as announced in the "Preview of Twenty-Third Annual Meeting" carried in the September, 1950 issue of THIS JOURNAL on pages 1249–1251, except that the topic "Operation and Maintenance of Electrical Equipment" was not included in the Operators' Forum. All technical program papers will be published in 1951 issues of the JOURNAL.

Entertainment Events

The social program was opened on Monday evening, October 9, by an informal reception for Federation and host association officers and wives. Following the reception, an interesting and entertaining variety show by professional talent was enjoyed by the members and their guests. Particularly amusing and amazing was an act featuring a sleight of hand and pickpocket artist, who demonstrated his "talent" on members chosen at random from the audience.

The Federation luncheon Tuesday noon was attended by about 250 persons. President Niles presided and presented the featured speaker, Abel Wolman, Professor of Sanitary Engineering, The Johns Hopkins University. Professor Wolman, speaking on "Reflection on National Water Policy," briefly commented on the policies and recommendations affecting sanitary interests as set forth in the June, 1950, report of the Water Policy Panel, Engineers Joint Council.

The Annual Federation Dinner and Dance, held in the beautiful Presidential Ballroom on Wednesday evening, October 13, as heretofore was the climatic social event of the meeting. At the dinner, which was attended by 555 members and guests, President Niles presented the annual Federation awards. Dancing followed, to round out a most enjoyable evening.

Ladies' Entertainment

An excellent program of social events planned by the local Ladies' Entertainment Committee, under the chairmanship of Mrs. S. E. Kappe, was extremely well received by the large group of ladies attending the meeting. Deeply appreciated was the cordial and gracious spirit of hospitality and friendliness with which committee members welcomed and entertained the visiting ladies.

The Monday afternoon tea party, generously and graciously financed and sponsored by the Maryland-Delaware Water and Sewerage Association, provided an excellent opportunity for all to meet and get acquainted. On Tuesday, the motor tour of Arlington, Alexandria, and Mount Vernon proved a delightful experience to all as they visited many of the historic national shrines of the area. A "Dutch treat" lunch at the Old Club, in Alexandria, was enjoyed on the return trip.

A tour of the interior of several important Washington public buildings on Wednesday attracted considerable attention. Among the places visited were the Bureau of Printing and Engraving, the beautiful Pan American Union Building, the Smithsonian Institution, the U. S. Capitol, and the Library of Congress. The day's activities were climaxed by return to the convention hotel for the Federation Dinner and Dance.

Men's Inspection Trip

The men's inspection trip, included on the technical program on Wednesday afternoon, proved a great attraction to those in attendance. Visits were made to the District of Columbia sewage treatment plant and the Pentagon Building sewage treatment plant. A partial sightseeing tour of Washington was included in the trip as the buses moved from one plant to the other through the city.

Manufacturers' Exhibit

Considerable attention was given by those attending the convention to the

exceptionally interesting and informative display of equipment and suppliers' products arranged by the Water and Sewage Works Manufacturers' Association. All space allotted for the exhibits was fully utilized.

BOARD OF CONTROL MEETS AT WASHINGTON

The two sessions of the Federation Board of Control, held on October 8 and 12 immediately preceding and following the 23rd Annual Meeting at Washington, were characterized by important business and good attendance. The pre-convention meeting was attended by 37 officers, directors, and proxy holders, and the October 12 session by 34.

New Officers

The following officers were elected by the Election Committee, which met following the session of the 1950 Board on October 8:

President: Ralph E. Fuhrman, Washington, D. C., for the year 1950–51.

Vice-President: Prof. Earnest Boyce, Ann Arbor, Mich., for the year 1950–51.

Treasurer: W. W. DeBerard, Chicago, Ill., for the year 1950–51.

Director-at-Large: E. Sherman Chase, Boston, Mass., for a 3-year term ending in October, 1953.

President-elect Fuhrman assumed office when the 1951 Board of Control held its organization meeting on October 12.

Federation Name Changed

Following through on the action initiated last year at Boston, the Board adopted amendments to the constitution and by-laws which consummated the change of name of the Federation to "Federation of Sewage and Industrial Wastes Associations." Other minor amendments to the constitution and by-laws further established the equality of interest in all forms of water pollution, whether of municipal or industrial origin.

Chlorine Supply Studied

Concerned over reported difficulties in the procurement of chlorine where needed for sewage disinfection, the Board created a special committee to investigate the situation and bring about an improved relationship between chlorine producers and consumers. An effort will also be made to insure the availability of chlorine for sanitation needs in the event of labor difficulties in production plants.

Priorities Resolution Adopted

The allocation of necessary materials for uninterrupted construction of water pollution abatement facilities was urged upon federal government authorities in a resolution adopted by the Board. Justification for high priority ratings was based on the need for water conservation in the fulfillment of industrial requirements, and the retarded progress in the construction of waste treatment works during World War II.

The resolution also urges the appointment of a qualified person to represent the Federation's field of interest in the federal agency having jurisdiction over materials allocation. A standing committee was created to carry through the objectives of the resolution.

Allocation of Sanitary Engineers

A third move of timely importance was the adoption of a resolution citing the critical supply of qualified sanitary engineers, and urging their allo-

cation to assignments in which they can be of greatest service in the event of a national emergency.

The resolution, to be directed to the appropriate federal authorities, recommends that professional sanitary engineers be declared in a critical category of skill, and that a competent authority be created to regulate their allocation to civilian and military services of greatest need.

1950 Awards

The following awards were conferred by the Board of Control and presented by President Niles at the Annual Dinner on October 11:

Honorary Membership—to Willis Wilford DeBerard, City Engineer of Chicago and Treasurer of the Federation since 1941.

Harrison Prescott Eddy Medal—to Daniel A. Okun for his paper "A System of Bio-precipitation of Organic Matter from Sewage."

George Bradley Gascoigne Medal—to Clarence E. Keefer for his paper "The Operation of the Back River Sewage Works, Baltimore, Md."

Industrial Wastes Medal—to Roy F. Weston, Robert G. Merman, and Joseph G. DeMann for their paper "The Industrial Plant Waste Disposal Survey."

Charles Alvin Emerson Medal—to Morris M. Cohn, for his long and devoted service to the development of the Federation and to the attainment of its objectives.

Arthur Sidney Bedell Awards (for service to Member Associations)—to Leland Bradney (Dakota), John C. Brigham (New York), Herbert B. Foote (Montana), L. L. Hedgepeth (Virginia), Theodore J. Lafreniere (Canada), Robert G. McCall (West Virginia), Edward Alexander Reinke (California), Frank S. Taylor (Oklahoma), LeRoy W. Van Kleeck (New England), William Hugh Weir (Georgia), Leonard O. Williams, Jr. (Rocky Mountain), Abel Wolman (Maryland-Delaware).

Also confirmed by the Board were late nominations for 1949 Bedell awards to John L. Strelow (Iowa) and William Thomas Lockett (Institute of Sewage Purification).

William D. Hatfield Awards (for outstanding operation reports)—to John W. Johnson of Buffalo, N. Y.; Walter A. Sperry of Aurora, Ill.; and William L. Edwards of Gowanda, N. Y. A "previous winner's" award was also made to John R. Szymanski of New Britain, Conn.

Twenty-Year Index Displayed

Editor W. H. Wisely announced that the 20-Year Index to the JOURNAL had been placed in distribution on September 21, and that sales were going forward at a highly satisfactory rate. Under the production plan authorized by the Executive Committee the receipts of sales will be retained by the printer until all costs are reimbursed after which the Federation will receive all revenue. The sale of about 1,000 copies will satisfy production costs, which level is expected to be reached before the end of the current year.

Membership

The Secretary reported the aggregate Active and Corporate membership in the 36 Member Associations of the Federation to be 5,043 as of September 30, 1950, as compared to 5,119 on the same date last year. Although a loss of about 1.5 per cent is represented here, it was considered gratifyingly small in view of the increase in Active Member dues that became effective last January 1. It was pointed out that a 13.5 per cent loss occurred in 1941 when Active Member dues were increased from $1.50 to $3.00.

An application for admission to the Federation by the *Abwassertechnische*

Vereinigung of Germany was presented to the Board and referred to the Executive Committee with power to act following further investigation. (This application was later approved by the Executive Committee.)

Financial Progress

The reports of the Secretary and Treasurer showed the net worth of the Federation to be $44,298.29 as of December 31, 1949. The Secretary reported further that 1950 operations were expected to yield a modest addition to surplus and net worth.

A balanced budget of $77,000 was adopted for 1951. This is essentially the same as the current operating budget except for the allowance made for an 8.4 per cent increase in JOURNAL printing and mailing costs, which became effective September 1, 1950. Anticipated net advertising revenue in 1951 is $38,500, as compared to an estimated $40,000 cost of printing and mailing the JOURNAL.

Committee Progress

Of particular interest in committee functions was the announcement by the Committee on Sewer Revenue Rates and Rate Structures that a comprehensive report will be published in April or May, 1951, by the Joint Committee of the American Bar Association and A.S.C.E. on the fundamental elements of water and sewage revenue rate structures. The report will be published and distributed by the Law College of Ohio State University.

The Committee on Standard Methods of Sewage and Industrial Wastes Analysis reported that preliminary planning of the 10th edition of "Standard Methods" is underway, with the aim of achieving publication by September, 1952. The committee is continuing its supervision and coordination of analytical methods research, with the aid of a new grant in the amount of $2,808 from the National Institutes of Health.

A proposed "Model Law" for state water pollution control authorities, as developed by the Federal Division of Water Pollution Control, is being studied carefully by the Legislative Committee.

The Sewage and Industrial Wastes Practice Committee noted the advanced stage of progress on the air diffusion and the chlorination manuals of practice, and anticipated the possible publication of both during 1951. The manual on paints and protective coatings was also reported to be near completion in first draft.

1953 Annual Meeting in Miami

Continuing its policy of selecting annual meeting locations three years in advance, the Board decided upon Miami, Fla., as the Federation's meeting place in October, 1953. St. Paul and New York City were previously determined as the locations for the 1951 and 1952 annual meetings, respectively.

Invitations for future meetings to be held at Cincinnati and Los Angeles were received by the Board and referred to the Meeting Place Committee.

R. E. FUHRMAN BECOMES FEDERATION PRESIDENT

Ralph E. Fuhrman of Washington, D. C., became the eleventh President of the Federation at the 1950 Annual Meeting of the Board of Control at Washington, October 12, 1950.

Following his early education in the public schools of Kansas City, Kans., Mr. Fuhrman graduated from the University of Kansas in 1930, receiving the degree of Bachelor of Science in Civil Engineering. In 1937 he received the degree of Master of Science in Sanitary Engineering from Harvard University.

After graduation from the University of Kansas, Mr. Fuhrman remained at that institution for a year as an assistant instructor in applied mechanics. He then became an assistant public health engineer with the Missouri State Board of Health. From 1932 to 1936 he was Sanitary Engineer at Springfield, Mo., leaving that position to take graduate work in sanitary engineering at Harvard University from 1936 to 1937.

In 1937 Mr. Fuhrman returned to the Missouri State Board of Health for a short period. Later in 1937 he became assistant superintendent of the District of Columbia sewage treatment plant. In 1942 he became superintendent, which position he now holds.

With this background of varied approaches to both municipal and industrial waste treatment, Mr. Fuhrman brings to the Federation's highest office a practical understanding and appreciation of the technical and administrative problems involved.

As a member of the Federation's Board of Control, first as Director from the Missouri Water and Sewage Conference (1932 and 1934–37) and then as Director from the Maryland-Delaware Water and Sewerage Association (1946–48), Mr. Fuhrman served on the Membership Committee (1934–37), War Service Committee (1943–44), General Policy Committee (1942–49), and Legislative Analysis Committee (1943–44). During his term as Vice-President (1949–50) he was a member of the Executive Committee and the Meeting Place Committee. He is at present President of the Maryland-Delaware Water and Sewerage Association.

Having seen the practical aspects of operation from both the operating and regulatory viewpoints, Mr. Fuhrman has a sympathetic understanding of the problems confronting operating, regulatory, designing, and legal personnel. In addition, he has a first-hand working knowledge of member association activities, which should be valuable in assessing the various problems arising in that area. His service and proven leadership will be extremely helpful in achieving the Federation's 1951 program of expanded service in the field of pollution abatement.

EARNEST BOYCE ELECTED VICE-PRESIDENT

As professor of Municipal and Sanitary Engineering in the College of Engineering, and Professor of Public Health Engineering in the School of Public Health, University of Michigan, Vice-President Earnest Boyce brings to the Federation's official family a background of experience and understanding of the problems and aims of the Federation that should go far in helping to reach the objectives before it. Before entering the educational field he had served as Assistant Engineer (1920–24) and then Chief Engineer and Director (1924–41) of the Division of Sanitation, Kansas State Board of Health.

Professor Boyce, through his activity on Federation committees, has demonstrated the superb quality of his technical and administrative ability. He has been a member of the Board of Control since 1936, first as Director from the Kansas Sewage Works Association (1936–40) and then as an ex-officio Director (1941 to date) by virtue of his chairmanship of the important Organization Committee. This committee is charged with the responsibility of promoting member association affiliations, the processing of such applications, and the approval of all proposed constitution and by-law amend-

ments in existing member associations. The functions of the Organization Committee are especially significant to the growth of the Federation and its relationship with its member associations.

In addition, Professor Boyce served as a member of the Legislative Analysis Committee from 1946 to 1948. He is at present also a member of the Executive Committee and the Meeting Place Committee.

IOWA AND LOUISIANA ASSOCIATIONS WIN 1950 MEMBERSHIP CONTESTS

The 1950 Federation membership contests, carrying prizes of $100 each, were won by the Iowa Sewage Works Association and the Sewage Works Section, Louisiana Conference on Water Supply and Sewerage. Both contests covered the year ended September 30, 1950.

In increasing its enrolled membership by 37 during the year, the Iowa Association outstripped runners-up in in the numerical increase race. Honorable mention in this category, with the gains recorded, goes to the New England Sewage Works Association (25), the Michigan Sewage and Industrial Wastes Association (23), and the New Jersey Sewage and Industrial Wastes Association (17). The Pennsylvania Sewage and Industrial Wastes Association and the California Sewage Works Association recorded gains of 15 and 14 members, respectively.

The Iowa Association, victor in the numerical increase contest, placed second in the percentage increase contest with 32 per cent, bowing only to the 50 per cent increase recorded by the Sewage Works Section of the Louisiana Conference on Water Supply and Sewerage. Undisputed third place was captured by the Swiss Association of Water and Sewage Professionals with 15 per cent. Further honorable mention is due the New Jersey Sewage and Industrial Wastes Association, the Montana Sewage Works Association, and the Sewage Works Section of the Maryland-Delaware Water and Sewerage Association, all with a 12 per cent recorded increase.

GERMAN ASSOCIATION JOINS FEDERATION

Approval of the petition for affiliation of the *Abwassertechnische Vereinigung* (German Sewage Technologists Association) by the Executive Committee, under previous delegation of such power by the Federation Board of Control at the Washington meeting, made the German organization the 37th member of association. The affiliation was effective as of October 8, 1950, date of the Board's provisional approval.

Admission of the German Association swells Federation active membership by 32 charter members included. Officers of the German Association are: Max Prüss, President; Franz Schrier, Vice-President; and Wilhelm Bucksteeg, Secretary-Treasurer. Karl Imhoff has been named as Director to represent the Association on the FSIWA Board of Control.

Reviews and Abstracts*

Proceedings of the Fourth Industrial Waste Conference. *Eng. Bull.*, **33**, No. 4. (Extension Series No. 68), Purdue Univ. (July, 1949).

This is a continuation of the papers presented at the Fourth Industrial Waste Conference. Previous abstracts have appeared in THIS JOURNAL, **22**, 8, 1092; and **22**, 10, 1380.

Disposal of Waste Cyanides by Electrolytic Oxidation. BY R. W. OYLER. Pp. 250–254.

Due to objectionable features in other treatment processes for cyanide-bearing solids containing interfering contaminants, a method of treatment by electrolytic oxidation was developed at the Guide Lamp Division plant of General Motors. The sludges are washed several times with hot water to remove free cyanide so the solids may be safely disposed of in a dump. The solution is heated, agitated with air, and electrolized using copper electrodes. A list is given of the equipment and its cost used in the work at this plant.

Incineration of Wastes from Large Pharmaceutical Establishments. BY C. H. P. ARBOGAST. Pp. 255–259.

Wastes from Lederle Laboratories consist of large amounts of boxes and of paper contaminated with putrescible animal and vegetable matter, small amounts of garbage, solvents, waste powders, and noncombustible materials such as glass. Combustibles, including sewage solids, are incinerated in a drier-incinerator built in two sections, an upper for drying wet materials and a lower for burning dry materials with the aid of forced draft. A description of the equipment and the method of operation is given.

A Waste Treatment Plant for Boardmill Wastes. BY M. F. KNACK. Pp. 260–265.

A system is described which handles wastes from two paperboard machines at the River Raisin Paper Company. Roof and clean water are eliminated from the sewers, some white water is used for showers to keep forming molds clean, some white water is heated and used in beaters and pulpers, and the final effluent is clarified and solids retained. The recovery program reduced mill waste volume from 5,000 g.p.m. to 1,600 g.p.m.

An Infilco Cyclator is used to remove solids with the aid of alum and activated silicate coagulants. Tests show reductions of 50 per cent in the 5-day B.O.D. and 92 per cent in suspended solids through this unit. The suspended solids content of the effluent is only 6 p.p.m. greater than that in the mill raw-water supply. Seventy per cent of the 7,240 lb. of solids recovered daily is volatile and represents the valuable portion of the sludge. Sludge is returned continuously to the process and experience has proved it not to be detrimental.

Wastes from the Processing of a Bale of Straw. BY D. E. BLOODGOOD, J. F. KINNAMAN, AND R. D. COLEMAN. Pp. 266–277.

A small rotary cooker was set up and the typical strawboard process using lime and sodium hydroxide was simulated. A bale of straw was graded according to sieve numbers, and one or more cookings were made with measured quantities of each grade to determine which produced the most paper and which the most waste.

Detailed tables are included showing results of 20 cooks, with separate results

* Please send to Federation headquarters all periodicals, bulletins, special reports, etc., which might be suitable for abstracting in THIS JOURNAL. Publications of public health departments, stream pollution control agencies, research organizations, and education institutions are particularly desired. Address such material: Federation of Sewage and Industrial Wastes Assns., 325 Illinois Bldg., Champaign, Ill.

for wash water, milling water, and composites. The study shows that portion retained between sieves 0 and 20 made up 88.8 per cent of the bale, and produced 94.5 per cent of the paper and only 79.2 per cent of the waste solids, which represented 83.8 per cent of the total potential B.O.D. The waste solids from a bale of straw amounted to 37.3 per cent of the bale weight.

Oil Separation in the Disposal of Refinery Wastes. By W. E. Howland. Pp. 278–284.

The author's views in regard to the latest design of the A.P.I. oil-water separator are expressed, with a brief description of the unit. He doubts the efficiency of the "film rupture trays" and approves of the latest change, which permits use of a single tank instead of a two-stage unit. A discussion of flow characteristics based on velocity, surface area, and Reynolds number values is followed by recommendations for more studies on turbulence and inlet design.

Reclamation of Oil in a Large Industry. By Bruce A. Barr. Pp. 285–289.

This gives a general discussion of various uses for oils, such as for fuel, lubrication, cutting purposes, and quenching, and the reclamation possible in each case. Specifically cited is the Warner Gear Division plant, where separators and centrifuges are used to reclaim oil which is again used.

Coagulation of Refinery Wastes by Twin Pilot-Plant Units. By R. F. Weston, R. G. Merman, and J. G. De Mann. Pp. 290–313.

The operations and results of tests are described for pilot plants designed to provide a higher type of treatment than gravity separation of oil and suspended solids from combined refinery wastes. One flexible unit was equipped to treat with caustic, acid, and coagulant, individually or in combination, to flocculate in parallel tanks, and to settle either in deep circular or shallow rectangular tanks. A pilot-scale Accelator unit was also set up, and concurrent studies were made with duplicate A.P.I. gravity separation tanks provided with supplemental aeration tanks and a biological filter. Experiments were also made on the dewatering of sludge using a continuous pre-coat pilot filter.

Considerable work was done under varying conditions, and tables and graphs are used in discussing results. Chemical precipitation can be expected to give efficiencies of about 90 per cent for oil, 80 per cent for suspended solids, 70 per cent for B.O.D., and 95 per cent for odor, when using alum alone. Higher efficiencies, or increased throughput without the loss of efficiency, can be obtained with the use of such a coagulating aid as activated silica or Fuller's earth. Sludge can be dewatered on the filter to about 45 per cent water content and incinerated satisfactorily.

Cyanide Waste Treatment by Ion Exchange Methods. By F. J. Losson, Jr., and D. E. Bloodgood. Pp. 314–326.

Laboratory-scale studies were made using large glass cylinders containing ion-exchange materials and aeration appurtenances. The process of ion exchange is described, but there is little discussion of the results of such tests alone. In treatment by aeration, thin films of waste were put through cylinders containing Rashig rings or porous tubes, with air being forced upward or through the tubes. Aerators were used alone and in conjunction with cation exchangers.

Hydrogen cation exchangers and porous-tube aerators together gave sodium cyanide reductions of 79 to 98 per cent, the degree depending on the rate of flow. All of the cyanide removed from the waste solution was easily and cheaply recovered through the use of a sodium hydroxide bath.

W. A. Hasfurther

Protecting Cracow Against Flooding by Increasing the Length of the Intercepting Sewer. By Stefan Szemplinski. *Gaz, Woda i Tech. Sanit.* (Polish), **24**, 187 (May, 1950).

The author first reviews principles of computing the backwater curve for one river flowing into a larger river at flood stage, and applies similar technique to determine the length of intercepting sewer required to satisfy backwater effect, on the assumption that an intercepting sewer is similar to a river. From computations

given, it is indicated that if the collector is reduced in length to the value proposed by others the upper reaches of the interceptor will be full because of the backwater effect, and flooding of the low-lying areas served by the interceptor will occur. Reference is made to British practice for discharge of untreated sewage to streams when dilution of 1:500 is available. At Cracow it is noted that the dilution factor in the Vistula River will be only 1:50. The author believes that construction of a complete sewage treatment plant at the end of the proposed left bank (short) interceptor is unwarranted, as the plant is designed for a population of 400,000, whereas the present population amounts to 200,000 and the major increase in population is expected to occur on the opposite bank. The inference is made that the municipality erred in this, as well as in planning to discharge the sewage from the right bank area into a small river discharging into the Vistula River 4 km. below the city of Cracow, and the feeling is expressed that an open sewer in greater Cracow is undesirable.

CONRAD P. STRAUB

Informal Progress Report for May 15, 1949–October 1, 1949 by Sanitary Engineering Department. The Johns Hopkins Univ., Baltimore, Md. JHUX-3 Spec. Rep. (Oct. 1, 1949).

The uptake of P^{32} by bacterial slimes similar to those commonly developing in traps, sinks, and drains has been studied both in the laboratory and in field investigations. Laboratory investigations indicate that P^{32} uptake is related to the area of the slime surface and is independent of slime thickness; to the immersion time by the approximate formulation $U = C\,t^n$ (where U is the uptake, n is the slope of the curve, t is the immersion time, and C is the y intercept and is constant for a given solution concentration); and to the initial concentration of radioactivity. Removal of the radioactivity by rinsing was proportional to immersion time, with thicker slimes showing less removal. Short-time rinsing was relatively ineffective, particularly after long immersion times. From this it was intimated that it would be impractical to wash out P^{32} that had been incorporated into the cell structure of bacterial slimes of pipes, traps, and vessels. In studying the effect of pH it was found that with a pH of 5 to 7, P^{32} uptake was highest and decreased most at high pH values (due in part to the detergent action causing slimes to slough from glass surfaces). Isotopic dilution, it was felt, should be accompanied by water dilution and should not be resorted to alone.

An analysis of slimes collected in the field from sinks, traps, etc., showed that both P^{32} and I^{131} were taken up by the slimes sampled. Some study was also made of the uptake of radioactivity by metals and showed that for a pH of 3.5, for the metals investigated, the degree of variation in uptake decreased as the initial concentration increased, differences were least at pH 7, and at pH 11 differences were related to detention time. Stainless steel was found superior to lead as a laboratory working surface.

CONRAD P. STRAUB

Waste-Treatment Cost Need Not Be Excessive. BY WENDELL B. GOODE. *Textile World*, p. 100 (Jan., 1950).

Varel Mills, Inc., has installed a treatment plant at Middleway, West Virginia, for handling 1 m.g.d. of wool-finishing wastes at a daily cost of about $30. Wool processing at Middleway includes dry-cleaning, carbonizing, washing, fulling, continuous-scouring, dyeing, and other finishing operations. The waste treatment plant at Middleway is the first ever to be built that provides complete treatment for wool-finishing wastes in their entirety.

The plant consists of the following equipment: rotary screen, chemical house containing three dry-feed machines and a chlorinator, mixing chamber, flocculation chamber, secondary settling tank, chlorine detention chamber, sludge settling basins, and pumping equipment. The plant was originally designed for 1-m.g.d. flow, with the expectation that alum, lime, and chlorine would effect satisfactory treatment. This expectation has proved largely true; however, during some operating periods it has been found economical to add clay.

Experience has indicated that as long as the same types of cloth are being run, little change in chemicals is necessary, except at irregular intervals when the

dyeing and carbonizing processes dump their effluent. An analysis sheet on a typical run showed the following reductions: B.O.D. 93 per cent (280 to 20 p.p.m.), total solids 64 per cent (1,530 to 550 p.p.m.), volatile solids 81 per cent (780 to 150 p.p.m.), suspended solids 90 per cent (300 to 30 p.p.m.), volatile suspended solids 91 per cent (179 to 16 p.p.m.)

To treat 8,464,000 gal. during a typical run, chemical costs were as follows: alum (6,000 lb.) $151.29, chlorine (240 lb.) $22.20, clay (2,300 lb.) $17.83, lime (3,000 lb.) $18.75. Thus, the cost of chemicals for this run was $24.83 per m.g. of waste.

R. K. HORTON

Disposal of Radioactive Wastes from Massachusetts General Hospital. By FRANK A. BUTRICO. Mass. Inst. of Tech. NP-1623 U. S. Atomic Energy Comm., Tech. Inf. Div., Oak Ridge, Tenn. (May 19, 1950).

A study was made of the discharge of radioisotopes from the Massachusetts General Hospital. Measurements were made of the I^{131} discharged and estimates were made of the discharge of P^{32} and C^{14}. It was found that 1.8 curies of I^{131}, about 0.65 to 1.3 curies of P^{32}, and about 10 millicuries of C^{14} were used annually. The amount of isotope discharged would be considerably lower, inasmuch as about 50 to 60 per cent of the administered dose of I^{131} is excreted in 48 hr. Samples were collected on 5 days when flow was the lowest to simulate most hazardous conditions. The concentration of activity discharged was compared with values proposed in the "Interim Recommendations for Disposal of Radioactive Wastes by Off-Commission Users" (Isotopes Division Circular B-6) and it was found that on 3 days the activity discharged exceeded the recommended values. However, NaI was added to the wastes before discharge, thus minimizing the hazard by means of chemical dilution. The following conclusions are drawn: 1) I^{131} is discharged in concentrations exceeding those recommended by the Isotopes Division, 2) for additional dilution in the hospital sewer system the radioactive wastes should be discharged at times of maximum sewage flow, 3) I^{131} wastes were reduced to a negligible hazard when discharged into the Boston Metropolitan sewerage system (dilution computed at about 70:1), 4) P^{32} does not constitute a problem at present, and 5) C^{14} does not constitute a serious hazard, due to negligible discharge. [*Abstractor's note:* Although the data presented are limited, it is felt that this is an excellent study. It would be desirable for sanitary engineers to familiarize themselves with the procedures employed, to cooperate closely with hospital staffs in their communities where isotopes are discharged with hospital sewage wastes, and to evaluate carefully the amount of radioisotope discharged.]

CONRAD P. STRAUB

Stream Sanitation in Florida. By EARLE B. PHELPS AND DAVID E. BARRY. Bull. Series No. 34, Florida Eng. and Indus. Exper. Sta. (May, 1950).

Water quality specifications are given for water usage by different interests, such as domestic supply, bathing, shellfish growing, and industrial needs, followed by a very lucid description of the natural, reversible, self-purification stream reactions.

An illustrative statistical treatment of drought flows given may be helpful to others making estimates of minimum flow conditions in streams, particularly those streams with incomplete available data.

A large part of the bulletin is devoted to a summary of stream flow and pollutional data on 32 major Florida streams. The area, mean and minimum flow over a specified period, the population, and the industrial load are factors listed for each watershed. The authors concluded that while there were certain areas in which the present polluted condition of the waters might fairly be said to represent a wasteful utilization of natural resources the preponderant group was suitable for every desirable purpose of recreation, wild life, industry, and domestic use.

K. W. COSENS

Book Reviews

Praxis der Abwasserreinigung (Practice of Sewage Treatment). By W. Husmann. Springer-Verlag, West Berlin, Germany. 140 pp. Price 10.50 DMark.

This is an elementary textbook on sewage treatment as practiced both in Germany and abroad. In general, it outlines only accepted methods, practices, and equipment and leans heavily on German developments and devices.

H. P. Orland

Soil Fertility and Sewage. By J. P. J. van Vuren, Dover Publications, Inc., New York, N. Y. 236 pp. Price $4.50.

The author, who has been actively concerned with municipal waste composting in South Africa, states that the theme of the book is "as old as the hills" and devotes a considerable part of his book to "soil husbandry," with a description of how the fertility of the earth's soil has been wasted through ignorance. He considers that the growth of modern deserts is not the result of natural conditions, but is caused by man. The wasteful actions are carried out at an ever-increasing rate. Citing the results of malpractices by quoting that "probably more soil has been lost (in the U.S.A.) since 1914 than in the whole previous history of the world" because of persistant single cropping, burning off vegetation, ruthless use of artificial fertilizers, ploughing and encouraging erosion, he concludes that only the principle of returning all refuse to the soil will make it possible for future generations to live. The processes of soil exhaustion are considered to be encouraged by the urban demand for cheap food and the ingenuity of urban dwellers in destroying and disposing of the organic waste products.

The utilization of urban waste products by composting garbage, nightsoil, and sewage sludge, a practice widely followed in the Union of South Africa, helps to restore the fertility of the land. The general principles of composting and the effects of various factors on the efficiency of composting are described in detail. Factors affecting the rate of composting, including pulverizing, rainfall, aeration, temperature, reaction, suitability of plant residues, activators and mineral nutrients, are illustrated by results and chemical analyses of the material. Studies and observations on fly breeding are given. Certain methods of composting are recommended and labor requirements and costs calculated. The physical and chemical characteristics of the finished product and its significant fertility value is described. A chapter on the general importance of organic manures, the importance of humus, mineral deficiencies, micro- and macrobiological activities, together with methods of application and responses, concludes this unusual book. Basically, the thesis of the book is that the underlying principles of Chinese agriculture are sound, but that the practice is unsanitary and that proper composting produces gratifying results. The book is interesting, semiscientific, and an expression of enthusiasm and faith. It can be recommended to all who have interest in the future of the country and to those who are immediately concerned with the preparation, handling, and disposal of human wastes.

Willem Rudolfs

Studies on Household Sewage Disposal Systems. (Part I). By S. R. Weibel, C. P. Straub, and J. R. Thoman. Environmental Health Center, U.S. Public Health Service, Cincinnati, Ohio. 260 pp., mimeo. (1950).

This 260-page report is divided into eleven major topics as follows: Introduction, Summary, Application of Research Results, Review of Literature, Survey of

Controls and Practices in Some Local Health Units, Study of Experimentally Operated Septic Tanks, Study of Septic Tanks in the Field, Sludge and Scum Accumulations, Laboratory Investigation of Sludge, Yeast as Starters, Experimental Investigation of Effect of Zeolite Softener Salts on Digestion, Survey of Information on the Freezing Aspects of Household Sewage Disposal Systems, and Appendices. The thoroughness of the study and the care exercised in reporting the results reflect much credit upon the investigators.

The literature survey covers 623 references extending back to 1892. Ten experimental studies other than this one are reported upon. A summary of design practices in the United States and in 12 foreign countries is presented.

Solicitation of information on controls and practices from 1,247 local health units in the United States brought a 64 per cent return. The survey indicated that controls are of recent origin and in practically all cases are lodged in the health department. The most frequent complaint is seepage to the ground surface, followed by odor nuisance, plumbing stoppages, and sewage backing into the cellar. The causes of difficulty in descending order of frequency were clogged tile fields, tank cleaning overdue, sewer clogged, and tank inlet clogged. Weaknesses in local controls were indicated in the general failure to inform householders of servicing responsibilities and in failure to make a preliminary examination of installation circumstances.

At the Environmental Health Center, 18 full-size septic tanks were operated under parallel operating conditions for periods up to a year. The tanks were dosed in rotation, each receiving eight intermittent doses a day, seven days a week. The amount of each of the eight doses was varied according to a pattern developed from the metered water use pattern at several households. The sewage used was a fresh sewage obtained from a combined sewer serving a residential hillside near the laboratory. Analyses on samples of tank influent and effluent included temperature, pH, solids, B.O.D., sulfide, grease, and bacteriological determinations. Suspended solids removal varied from about 44 to 82 per cent. Limited data on grease and B.O.D. indicated removals as high as from 71 to 92 per cent and 64 to 84 per cent, respectively. There was a tendency on the part of the multicompartment tanks in the 500-gal. capacity range to store more sludge with less disturbance to operating efficiency than in single-compartment tanks. The early dropping off of efficiency in the smaller capacity tanks was evident. These comparisons are made on the basis of solids removal efficiency, which, though important, may not be the only factor to be considered in connection with clogging of the soil absorption system.

Field inspections were made in nine geographical areas in the United States covering some 300 residential septic tanks in all. This survey indicated an average of 2.5 bedrooms per dwelling and an average of 1.5 persons per bedroom. Metered water usage at 170 residences averaged 49 g.p.c.d. in summer and 39 g.p.c.d. in winter. Sludge and scum accumulation data on 205 tanks of all types showed the average sludge plus scum accumulation trend was upwards of 3.4 cu. ft. per person per year during the first year, dropping off (presumably due to digestion and compaction) to 1.34 cu. ft. per person per year at the 7-year mark. Beyond the 7-year point the rate of accumulation remained nearly constant. The distribution was about 0.42 cu. ft. of scum and 0.92 cu. ft. of sludge per person per year at about the 7-year point and beyond. If sludge and scum accumulation are considered a rough measure of efficiency, tank capacity appears to be an important factor, there being much less accumulation in the smaller tanks. Tanks receiving all wastes appeared to accumulate 11 per cent more sludge and scum than tanks receiving bathroom wastes only. Data on 150 tanks indicated that about 27 per cent of the total scum thickness will be above the water line.

Of 244 tanks examined for structural state, it appeared that corrosion was most severe inside the tank at and above the water line. In general, pre-cast concrete, tile, and brick stood up well for 20 years; poured-in-place concrete, for at least 10 years (no data available for older tanks). Steel tanks averaged a 7-year useful life, but individual tanks lasted as long as 12 years. Wood baffles were found sound in tanks as old as 7 years.

Bottle experiments on sludge seeding indicated that a sewage to sludge volatile solids ratio of 1 to 4.4 would reduce digestion lag. Yeast showed no value as a "starter." Salts from zeolite softeners (sodium, calcium, and magnesium chlorides) up to 0.4 per cent have no detrimental effects on digestion, but a concentration of 1.2 per cent was detrimental Salt-water stratification may occur.

A carefully constructed system with gravel packing of the tile lines and insulation of pipes under surfaces usually cleared of snow will rarely freeze if it is in continuous use.

Conclusions pertaining to design which appear warranted from this study are: Average per capita daily water use 49 gal. in summer, 39 gal. in winter. A household septic tank should function as a settling tank, a digestion tank, and a sludge storage tank. On the basis of suspended solids removal, there is little difference between uncompartmented tanks of rectangular, oval, and circular shape of approximately the same capacity and depth. Some type of compartmentation appears desirable. Some means of cleaning each compartment of a multiple-compartment tank should be provided. Minimum tank capacity should be 500 gal.

For single-family suburban dwellings during the first 5 years of operation, or after cleaning, the average per capita accumulation of sludge and scum can be approximated by the equation $V=17+7.5Y$ where V is the volume of sludge and scum in gallons per capita and Y is the years of service. This equation holds best for tanks with liquid capacity of about 125 gal. per capita. Limited study of 500-gal. rectangular tanks showed no significant difference in performance between a standard tee outlet and a baffled weir outlet.

PAUL D. HANEY

Ion Exchange Resins. By ROBERT KUNIN AND ROBERT J. MYERS. John Wiley and Sons, Inc., New York, N. Y. 1950. 212 pp. Price $4.75.

This is claimed to be the first book to assemble, digest, and clarify the essential parts of the voluminous literature on the increasingly important subject of ion exchange resins. Intended as a reference for the research worker, as an introduction for the inexperienced reader, and as a guide for the engineer, it covers thoroughly the phenomenon of ion exchange, including the underlying theory, the usefulness of resins, the operational and engineering data associated with them, and the methods of use in both laboratory and industry.

Considerable previously unpublished data on commercial resins are included. Although but very little is included that refers directly to stream pollution or sewage and industrial wastes treatment, the background content of the book should prove of great interest to water, sewage, and industrial wastes personnel from the national and state control levels to the operating level.

An excellent bibliography of 651 references is included, as are many useful tables and illustrations.

H. P. ORLAND

Public Health Engineering, Volume II. By EARLE B. PHELPS. John Wiley & Sons, Inc., New York. 1950. Price $4.00.

The contents of this second volume constitute Part III—The Food Contact—of the two-volume work. Parts I and II—The Air Contact and The Water Contact, respectively—are contained in Volume I, which was reviewed in THIS JOURNAL, **20**, 6, 1148 (Nov., 1948). The book illustrates those principles of sanitation which, applied to the production, handling, and distribution of food, have direct public health significance.

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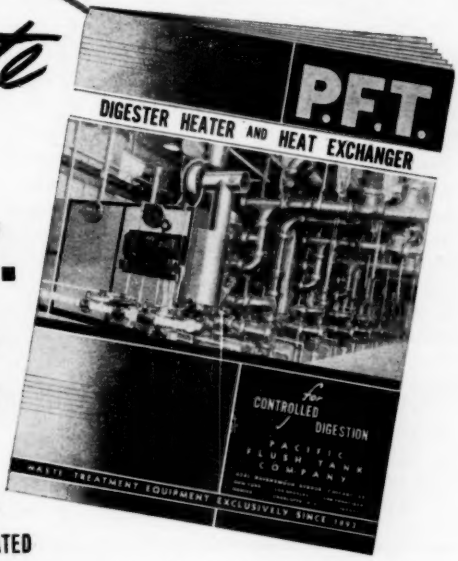

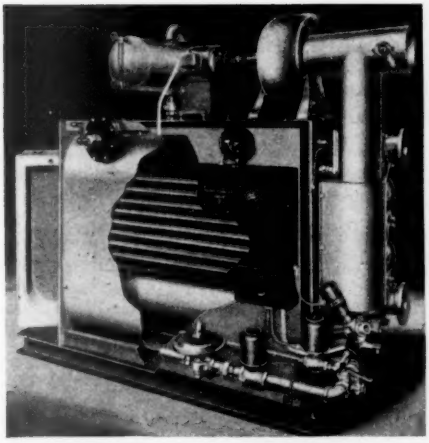

In this book, comprehensively presented for the first time, is data, collected over the past decade, on the heating of sludge undergoing digestion. Construction and operation of the P.F.T. Heater & Heat Exchanger is covered in detail. Typical views of the more than 300 installations are reproduced. Also presented are details of construction such as the cut-away view at left. You will find it a worthwhile contribution to the art and science of waste treatment.

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Proceedings of Member Associations

CANADIAN INSTITUTE ON SEWAGE AND SANITATION

The 17th Annual Meeting of the Canadian Institute on Sewage and Sanitation was held at Bigwin Inn, Lake of Bays, Ontario, Canada, September 11–13, 1950. The total registration was 265.

The opening session on September 11 comprised mainly a discussion of construction, cost, and financing of sewer connections, under the guidance of A. E. Chalmer, Peterborough, Ont. The afternoon session was devoted to a symposium on "Pollution in the Boundary Waters," with papers as follows:

"Investigation of Pollution in the Boundary Waters," by A. E. Berry, Ontario Department of Health, Toronto.

"Treatment of Oil Wastes," by A. D. McRae, Imperial Oil Ltd., Sarnia, Ont.

"Treatment of Phenol Wastes," by A. V. DeLaporte, Ontario Department of Health, Toronto.

"Treatment of Synthetic Rubber Wastes," by L. D. Dougan and J. C. Bell, Polymer Corp. Ltd., Sarnia, Ont.

"Treatment of Distillery Wastes," by C. T. Carson, Hiram Walker and Sons Ltd., Walkerville, Ont.

"Disinfection of Industrial Wastes,"

(*Continued on page 28a*)

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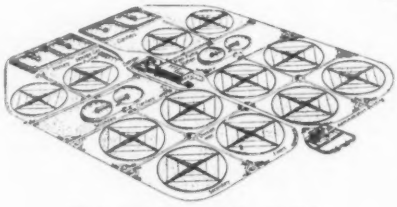

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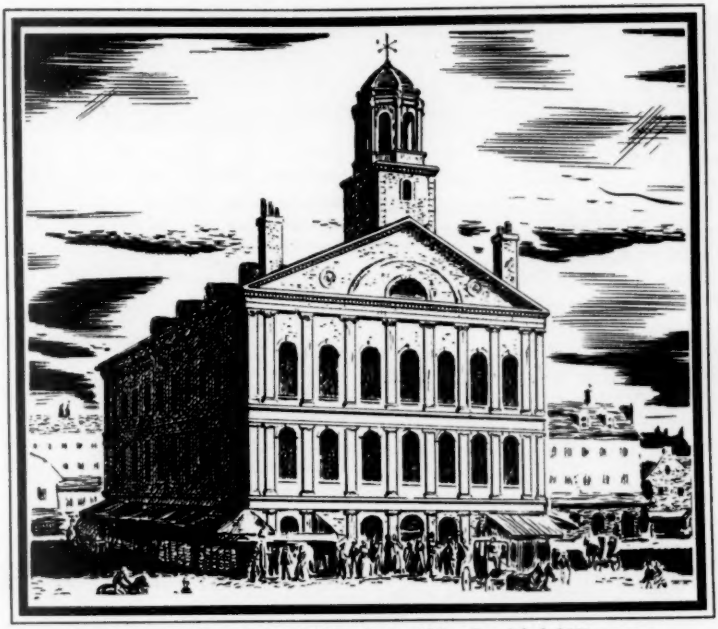

Boston's Faneuil Hall, popularly called "The Cradle of Liberty", as it looked 100 years ago

Boston, Massachusetts, has cast iron water and gas mains in service that were installed more than a century ago. In those days, modern pavements were unknown; labor costs were low. Today, the expense of unnecessarily frequent repairs to underground mains, or untimely replacements, and consequent restoration of costly pavements, is a risk you cannot afford to gamble with. Cast iron pipe has an established record of long life and low maintenance. It effectively resists corrosion and posesses the four strength factors so necessary to meet the stresses imposed by modern traffic and crowded underground construction. These are shock, crushing, bursting and beam strengths. No pipe deficient in any of these strength factors should ever be laid in paved streets of cities, towns and villages.

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This was followed by a guided discussion on refuse collection and disposal under the chairmanship of G. H. Baker, North York, Ont.

Dinner on September 11 was accompanied by entertainment under the auspices of the Canadian Sanitation Equipment Association.

During the morning session on September 12, in a guided discussion on miscellaneous municipal problems, D. A. R. McCannel, city engineer, Regina, Sask., acted as chairman. At this session, H. J. McGough, general manager, Ontario Highway Construction Safety Association, Toronto, spoke on "Lives or Lucre," and N. J. Goebelle, city engineer, Galt, Ont., described the sewer construction program in that city.

The afternoon was devoted to a Field Day, at which various games and contests were enjoyed before the Annual Banquet and dancing in the evening.

Papers presented on September 13 included:

"The Orillia Sewage Treatment Plant," by Stuart Keyes, assistant engineer, Water and Light Commission, Orillia, Ont.

"Maintenance of Sewers During Floods," by W. L. Wardrop, engineer of water works and sewerage, Winnipeg.

"Municipal Administrative Problems," by N. MacNicol, Forest Hill, Ont.

Throughout the meeting, several sessions of the Club Room, under the auspices of the Canadian Sanitation Equipment Association, were enjoyed by the delegates.

Officers elected to serve during 1950–51 were:

President: D. A. R. McCannel, Regina, Sask.

(*Continued on page 30a*)

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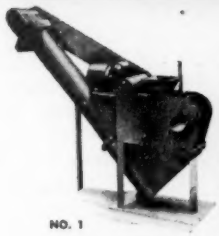

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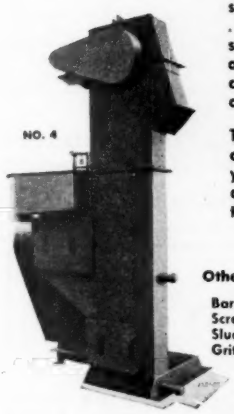

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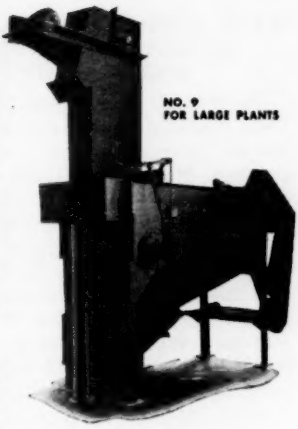

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A. E. Berry,
Secretary-Treasurer

WEST VIRGINIA SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

The Fourth Annual Meeting of the West Virginia Sewage and Industrial Wastes Association was held at the Prichard Hotel, Huntington, W. Va., on September 14–15, 1950. A total of 125 was registered for the meeting.

The meeting was opened on the afternoon of September 14 by President Edward Shroyer, following which Federation Vice-President Ralph E. Fuhrman acquainted the group with recent developments and services offered by the Federation.

"Coal Washery Wastes Problems" was an outstanding paper by Lyhle Gillenwater, engineer, West Virginia State Water Commission. This was a pioneer paper in this field and presented results of studies by the Commission.

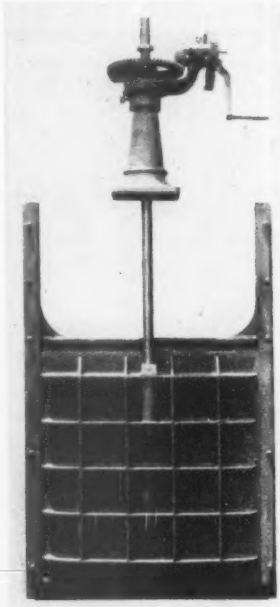
An inspection trip was then taken to the Truax-Traer coal preparation plant at Ceredo, West Virginia. This plant illustrated the latest developments in coal washing and included a treatment system for removal of coal fines.

"Legal Aspects of Stream Pollution Control," by D. J. Savage, chairman, State Water Commission, Charleston. It gave the group a statement of policy by the state stream pollution control agency and pointed out the obstacles encountered.

Other papers presented at the meeting included:

"Federal Water Pollution Control Activities in the Ohio River Basin,"

(*Continued on page 32a*)



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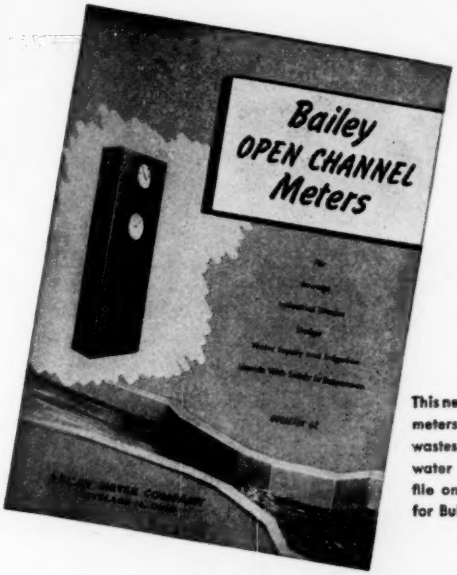

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by W. W. Towne, officer in charge, Ohio and Tennessee Drainage Basins, U.S.P.H.S., Cincinnati, Ohio.

"Fundamentals of Sludge Digestion," by R. G. McCall, assistant director, Division of Sanitary Engineering, State Health Department, Charleston, W. Va.

"Sludge Digestion Equipment," by Carl Wright, sales engineer, Pacific Flush Tank Co., Chicago, Ill.

"Operation of Activated Sludge Plant at Hopemont Sanitarium," by W. G. Ehlen, operator.

"Operation of High-Rate Trickling Filter Pilot Plant on Chemical Wastes," by P. F. Cunningham, Service Department, Monsanto Chemical Co., Nitro.

"Neutralization of Acid Wastes," by H. L. Jacobs, Engineering Service Division, E. I. du Pont de Nemours and Co., Wilmington, Del.

"Problems of Synthetic Chemical Industry," by H. D. Lyon, chemical engineer, Carbide and Carbon Chemical Corp., South Charleston.

At the annual business meeting officers were elected as follows:

President: D. V. Moses, Charleston.
1st Vice-President: H. W. Speiden, Morgantown.
2nd Vice-President: A. R. Todd, Wheeling.
Secretary-Treasurer: R. G. McCall, Charleston.
FSIWA Director: H. D. Lyon, South Charleston.

R. G. McCall,
Secretary-Treasurer

ROCKY MOUNTAIN SEWAGE WORKS ASSOCIATION

The 1950 Annual Convention of the Rocky Mountain Sewage Works Association was held in Santa Fe, N. Mex., September 27, 1950.

The meeting was welcomed by Mayor Ortiz, Santa Fe, following which C. E. Schwob, chief engineer, Stream Pollution Division, U.S.P.H.S., Washington, D. C., and R. F. Poston, chief engineer, Southwest Division of Stream Pollution, U.S.P.H.S., spoke on the national and divisional activities being carried on under Public Law 845.

Other papers presented at the meeting included:

"Lagooning of Waste Material," by W. Gahr, chief sanitary engineer, Colorado State Health Dept., Denver, Colo.

"Know What Your Sewage Works Are Doing," by G. Riepe, Builders-Providence, Inc., Chicago, Ill.

"Radioactive Wastes Disposal," by J. F. Newell and C. W. Christenson, Los Alamos, N. Mex.

At the Annual Business Luncheon, the following officers were elected:

President: S. Gass, Lordsburg, N. Mex.
Vice-President: R. Sherard, Cheyenne, Wyo.
Secretary-Treasurer: C. H. Coberly, Denver, Colo.

C. H. Coberly,
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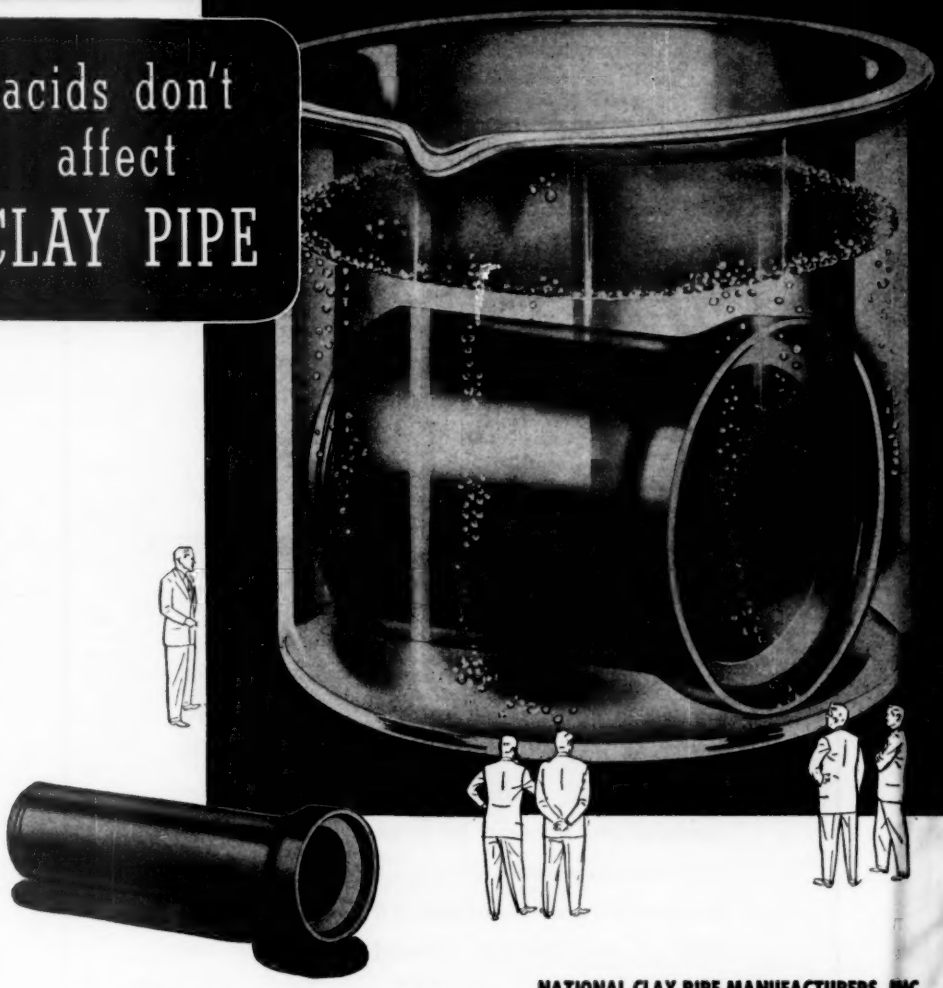

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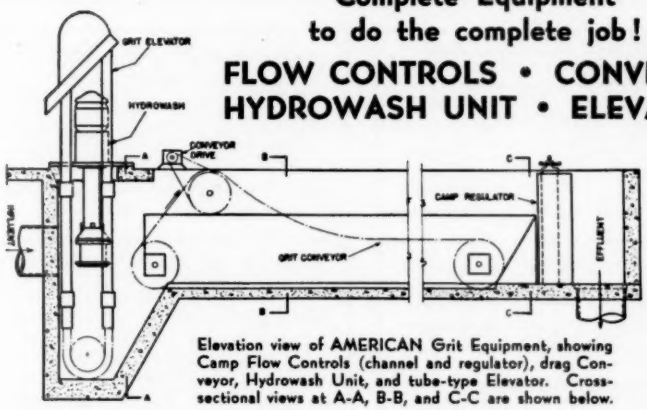

Elevation view of AMERICAN Grit Equipment, showing Camp Flow Controls (channel and regulator), drag Conveyor, Hydrowash Unit, and tube-type Elevator. Cross-sectional views at A-A, B-B, and C-C are shown below.

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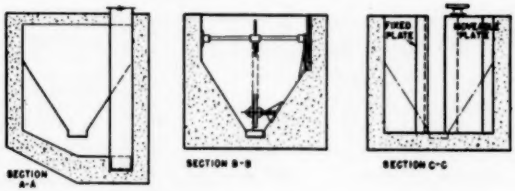

FLOW CONTROLS—exclusive Camp Control Section and Regulator maintain constant optimum velocity for effective grit settling, regardless of rate of flow through plant. Velocity can be easily and instantly adjusted to meet changing conditions.

CONVEYOR—single strand, continuous drag type carries grit from channel to hopper for washing and removal.

HYDROWASH UNIT—washes grit free of organic matter by producing a turbulent downflow recirculation of liquor in grit hopper.

ELEVATOR—totally enclosed, tube type, for slow and continuous removal of washed grit from the hopper. Grit drains as it is being elevated through the tube.

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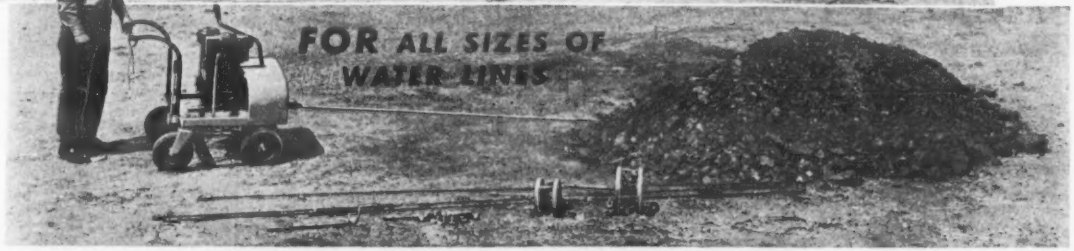

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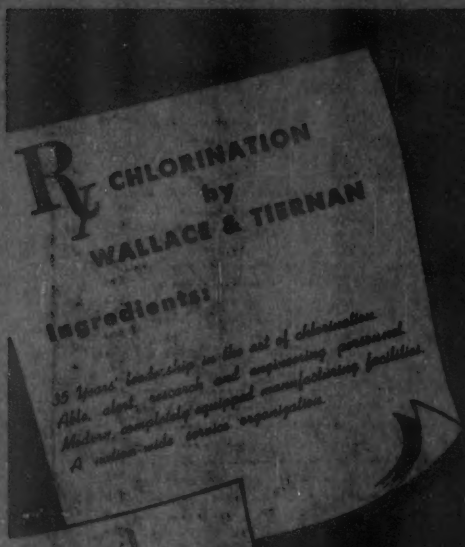

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